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EDITORIAL NOTES.

SIR AUBREY STRAHAN, K.B.E., Sc.D., LL.D., F.R.S., retired in July from the post of Director of the Geological Survey. He is succeeded by Dr. J. S. Flett, O.B.E., F.R.S., who has hitherto been Assistant Director of the Scottish branch. Mr. G. W. Lamplugh, F.R.S., Assistant Director for England and Wales, lately President of the Geological Society of London, has also retired. from the Survey.

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WE greatly regret to announce the death of Dr. Wheelton Hind, which took place on June 21 after a short illness. Owing to want of space an appreciation of his geological work is held over till next month. We have also in hand a paper by Dr. Hind on the Distribution of British Carboniferous Nautiloids, received only a few days before his death; this it is hoped to publish very shortly. Dr. A. Scott, of Stoke-upon-Trent, has kindly agreed to correct the proofs and see the paper through the press

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THE 88th annual meeting of the British Association for the Advancement of Science will be held at Cardiff from August 24 to August 28, 1920, under the presidency of Professor W. A. Herdman, C.B.E., D.Sc., Sc.D., LL.D., F.R.S., who will in his address give a general survey of Oceanography, and will deal with certain special problems in detail. The meetings of Section C (Geology) will be held in the Technical College. The president of this section will be Dr. F. A. Bather, F.R.S., and the secretaries are Dr. A. R. Dwerryhouse, Dr. W. T. Gordon, Dr. G. Hickling, and Professor A. H. Cox.

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THE Geophysical meetings of the Royal Astronomical Society for next session have been fixed as follows: November 5, Geodesy; December 3, Terrestrial Magnetism; February 4, to be arranged; March 4, Seismology; May 6, Meteorology; June 17, Geodesy. All Fellows of the Geological Society are invited to attend, and fuller particulars will appear in *Nature*, or can be obtained on application to the Assistant Secretary, Royal Astronomical Society, Burlington House, W. 1.

We have received from the Yorkshire Geological Society a circular setting forth that the Society is anxious to develop the study of Yorkshire rivers along the lines that have proved so fruitful in America. With their customary enterprise the Council have formulated a comprehensive scheme, for which they desire to enlist the aid of workers in all cognate sciences, whether members of the Society or not. As a matter of fact the work was begun in the Washburn valley last summer, and will be continued there, but it is hoped to extend it to other rivers throughout the county. The circular very wisely points out that a precise knowledge of tectonic structure is of fundamental importance in such a study, since this must affect the origin and evolution of the rivers; hence workers are invited in the first instance to record with precision the dip of the rocks in their respective areas. This is not quite so easy as it sounds at first, as all field-workers are well aware, owing to landslips, surface-creep, current-bedding, and other causes which need not be specified here. The importance of a record of faults and dominant joints is also insisted on. Besides these purely geological points, information is also desirable as to records of rainfall and the heights attained by floods and their frequency. Recent experiences in Lincolnshire have demonstrated the geological potency of sudden floods. With regard to the actual carrying out of the work, it is proposed, wherever possible, to form local committees, and all those interested are invited to communicate with the Secretary, Mr. H. E. Wroot, Pollard Lane, Bradford.

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The Government has now introduced into Parliament the promised Bill for the establishment of a Ministry of Mines, and, frankly, it is a very disappointing document. It is a good point, in view of economy, that the Ministry is to be a Department of the Board of Trade and not entirely new and independent, but beyond this we find little to praise. The provisions of the Bill are almost entirely concerned with coal-mining, and non-ferrous mining is only once specifically mentioned. It is provided that the Minister *shall* appoint a committee to advise him regarding coal, and that he *may* appoint a similar one to deal with other mines and quarries. We must hope that the metalliferous mining industry will make its needs known with sufficient force in the proper quarters, so that more consideration may be shown to an important industry by the Act in its final shape.

ORIGINAL ARTICLES.

Beerbachite at the Lizard.

By Professor T. G. Bonney, Sc.D., F.R.S.

IN my paper on the Lizard this rock is mentioned, but without a specific name, for I had not then seen the figure given in 1898 by Rosenbusch (*Elemente der Gesteinslehre*, 1898, p. 51). He calls it Beerbachite, and describes it on p. 219 as one of his *Ganggesteine*, among those *von malchitischem Habitus*, quoting an analysis. The name appears to have been given by Chelius to a rock from Frankenstein in the northern Odenwald, where it forms small veins in a gabbro, and has the following analysis: $SiO_2 = 47{\cdot}21$, $Al_2O_3 = 20{\cdot}52$, $Fe_2O_3 = 7{\cdot}48$, $FeO = 5{\cdot}32$, $MgO = 4{\cdot}16$, $CaO = 8{\cdot}63$, $Na_2O = 5{\cdot}17$, $K_2O = 0{\cdot}33$, $H_2O = 0{\cdot}34$, $P_2O_5 = 0{\cdot}46$, with 0·19 FeS_2 and 0·10 hygroscopic water. He states that the rock is fine-grained to compact, not lustrous, grey to pale grey in colour, consisting of a panidiomorphic mixture of labradorite and diallage, with a variable amount of hypersthene and magnetite, and that olivine-bearing varieties occur. In these commonly a brown hornblende replaces the diallage, in which the above-named constituents are pœcilitic. He states that beerbachite also occurs in gabbro near Harzburg and in the Isle of Mull.

At the Lizard the best outcrops of the rock are near Luggar Cove, to the south of Porthoustock, and I call it in my diary for July 6, 1894, when I particularly studied that part of the coast, "the brown-speckled rock," but it occurs, sometimes in considerable force, from near St. Keverne to the neighbourhood of Porthallow,[1] and I observed and collected it, a few years earlier, from the crags north of the Balk, where, however, it is less well exposed and rather more weathered. The following shortened extract from my diary for 1894 (which is illustrated by sketches) may serve to show the curious mixture of rocks near the shore to the north of Crousa Down. In certain places the gabbro itself varies much, a coarse variety, with diallage crystals sometimes a couple of inches in diameter, occasionally appearing in irregular patches and even in little tongues in the finer gabbro. The "brown-speckled" rock breaks into the gabbro, including fragments, patches, and streaks of it, a few inches or even more in length and perhaps one to three in diameter, which often assume a foliated structure. The speckled rock also not seldom appears to be "porphyritic". The crystals, which may run to about

[1] I studied the coast north of Crousa Down, from St. Keverne, in 1890, with my friends General McMahon and Canon Hill, and again in 1894 with the latter. I revisited it in 1908, when staying with Dr. Flett at Kennack Cove, to discuss sundry points on which we were not agreed, but do not remember that we used then the word beerbachite; and have since seen a little of the neighbourhood in 1909 and 1912.

half an inch in length, are "dead white", like those in the gabbro, and often occur in scattered "coveys". Occasionally they are joined, and include a small crystal of diallage, so they become difficult to distinguish from the smaller gabbro fragments. In fact, it looks as if the "brown-speckled" rock had occasionally partly melted down bits of the gabbro, destroying the augite rather than the felspar, and had softened and drawn out other patches, so that "a process analogous to what Professor Sollas has described in the Carlingford granites has happened here". Dykes of a compact "greenstone" cut both these rocks, but are neither abundant nor thick; seldom, I think, more than 4 or 5 feet.[1] All along the coast to north of Porthoustock we find (1) gabbro (the dominant rock), (2) next to it the "brown-speckled", then (3) the greenstone, much less abundant. So there is no justification for colouring all this part greenstone, as in the Survey Map. But I think the beerbachite at the Lizard must occur in rather thicker masses than it seems to do in Germany. Under the microscope my best slices of beerbachite (I have about seven in all) contain a rather strongly pleochroic hornblende, pale to rich brown, in hypidiomorphic grains, and of rather stumpy form, together with a granular augite more irregular in outline. The felspar (labradorite), also granular in outline, is in good preservation, and so is the iron-oxide, which occurs in rather small but irregular, rather numerous grains. I cannot certainly identify hypersthene or ægirine. Occasionally the felspar of the beerbachite becomes rather elongated, and the hornblende less granular close to a junction with the gabbro. One slice distinctly shows the partial melting together of the two rocks. Though it does not appear to have any marked chemical difference from several other "greenstones"[2] it seems to be so persistent in its structure and to exhibit such mineral peculiarities, that we must, I think, add beerbachite to the crystalline rocks of the Lizard, as has been already done by Dr. Flett in *The Geology of the Lizard and Meneage* (1912), where it is described briefly on p. 110 and a figure given at p. 101.

[1] These, as a rule, are not welded to the gabbro, beerbachite, or serpentine, as the troktolite is to the last-named, so I regard the beerbachite as the forerunner of the "greenstone" (basaltic) dykes so common on the eastern coast of the Lizard.

[2] See the analysis quoted in Rosenbusch's *Gesteinslehre* and Flett & Hill's *Geology of the Lizard*, etc.

Notes on the Fauna of the Lower Devonian Beds of Torquay.

By F. R. Cowper Reed, Sc.D., F.G.S.

(*Concluded from p. 306.*)

Homalonotus (*Burmeisterella*) *Champernownei* Woodward.

1881. *Homalonotus Champernownei* Woodward, Geol. Mag., pp. 489, 528, Pl. XIII.
1882. *Homalonotus Champernownei* Woodward, ibid., p. 157, Pl. IV, fig. 3.
1918. *Homalonotus* (*Burmeisterella*) *Champernownei* Reed, Geol. Mag., pp. 315, 325.

The diagnosis of this species given by Dr. Woodward in 1881 may be summarized as follows: Body with little or no signs of trilobation. Glabella oblong, with three pairs of lateral spines and three median spines, the anterior one apparently double. No evidence of cheek-spines. Eyes nearer genal border than in *H. armatus*, and rostrum more prominently developed. Thorax composed of thirteen segments with broadly expanded pleuræ; each axial ring with pair of widely separated spines. Pygidium imperfectly known. Total length of type-specimen 8 inches; breadth (measured along curve of thorax at widest part) $3\frac{3}{4}$ inches. Spines on thorax about 1 inch apart.

The pygidium from the same locality, which Woodward described and figured in 1882 (op. cit. supra) as probably belonging to this species, possesses about twelve rings on the narrow axis and a smooth terminal piece; the anterior rings are ornamented with a double row of spines. The lateral lobes show about six pleuræ, which die out near the margin, and a smooth, slightly elevated border is present. The extremity of the pygidium is produced into a blunt spine or mucro. But the specimen is poor and considerably broken and distorted, as the original figure shows.

There are two specimens in the Torquay Museum, labelled "33/6 Lincombe Slates, Lincombe Drive", which, judging from the matrix in which they are preserved and their state of preservation, come from the same horizon, and of which the larger one at any rate may be referred to the same species as Woodward's above-mentioned pygidium. It is in good condition, though it only shows the right side and axis, but the end of the pygidium is broken off. The general shape is triangular, and it is pointed behind, the mucro being stout and cylindrical, but of uncertain length. The axis, which measures about 30 mm. in width at the front end, is elongated conical, convex, and well-defined by axial furrows; it consists of an annulated anterior portion, about 42 mm. long, composed of eleven rings (of which the last three are not separated at the sides)

and of a non-annulated smooth posterior part beyond the base of the seventh pair of lateral pleuræ, which is imperfect and only 10 mm. in length, but seems to have measured about 20 mm. There is a pair of small tubercles or spines on the first axial ring, and also on the third, fourth, fifth, and sixth, and possibly on the seventh, but not on the other rings. The articulating half ring at the front end of the axis is marked off by a strong furrow, which is continued on to the lateral lobe, so as to separate off a large triangular articulating surface from the first pleura. The pleural lobe, which is perfect, shows seven pleuræ, but the seventh one is very small. The pleuræ are broad, low, and flattened, and the first one carries a large low tubercle at about half its length (or rather more), while the fourth pleura has a similar tubercle at about one-third its length, thus resembling *H. bifurcatus*. The other pleuræ are smooth. There is a smooth border of regular width round the pygidium, for the interpleural furrows do not reach the margin. The other smaller specimen has the same general characters, but seems somewhat more elongated, and there are no tubercles visible on the pleuræ or axis, but this may be due to immaturity or to individual variation, if we consider that Clarke[1] has made out his case for a similar variation in the allied tuberculated species, *H. Herscheli* Murch.

An imperfect glabella from New Cut, in the Sedgwick Museum (S. 8), measuring about 20 mm. in length, shows the lateral tubercles and the anterior median one, but the posterior part of the glabella is missing, and nothing of importance can be added to Woodward's description. There is, however, an interesting thoracic ring (S. 4) from the same locality and in the same collection which retains one of the pair of spines on the axis in an unbroken condition—a most unusual circumstance. The width of the axis in this specimen is 38 mm., according to the dimensions of the one perfect side, and the distance between the spines at their base is 22 mm. The complete spine rises up suddenly from the surface, and is directed obliquely outwards; it is straight, cylindrical, and slender, tapering regularly to a sharp point, and its length is 18 mm.

Another thoracic ring (S. 4*a*), with the axial spines 32 mm. apart, from the same locality and in the same collection, shows clearly the broad, flat articulating band on the front edge, nearly as broad in the middle as the ring itself, but near the axial furrow or constriction decreasing slightly in width. The strong, sharply impressed groove which marks it off from the ring is continued on to the pleura on each side so as to become the pleural furrow. The outer portion and tip of one pleura (S. 7) from the left side of the thorax shows this so-called pleural furrow well. This pleura has a flattened and rather rapidly broadened subspatulate extremity, with the anterior edge

[1] Clarke, *Foss. Dev. Parana* (Mon. Serv. Geol. Miner. Brasil), vol. i, p. 93, pl. iii, figs. 1–4.

of the pleura straight or slightly concave, and the "pleural" furrow, which is nearer to it than to the posterior edge, is subparallel and dies out some distance before reaching the subtruncate rounded tip. The posterior edge of the pleura is strongly arched backwards, making a convex curve, and at the posterior outer angle of the tip bears a small but distinct marginal tubercle, which seems to be unique.

The relations of *H. Champernownei* to *H. armatus* Burm. were briefly discussed by Woodward in 1881. We may here especially draw attention to the close resemblance of the pygidium in the Torquay Museum to one of those figured by Koch,[1] under the name *armatus*, but the number and position of the spines on the axis of *H. Champernownei* are distinctive features. Woodward also commented on its resemblance to *H. elongatus* Salter, and this is specially worthy of note, though only the pygidium of the latter is known with certainty. But, as I have pointed out in my paper on the classification of the genus,[2] we cannot strictly refer it to the same group as *H. Herscheli*, though Woodward regarded the latter as one of the two nearest allied species.

Horizon.—"Red Homalonotus Beds" ("Lincombe and Warberry Grits" = Staddon Grits).[3]

Locality.—New Cut (= Lincombe Drive), Torquay. (S. 8, 11(?), 13(?), 4(?), 7(?); T. $\frac{3}{6}^{3}$.)

Homalonotus (*Burmeisterella*) *elongatus*, Salter.

1865. *Homalonotus* (*Burmeisteria*) *elongatus* Salter, Mon. Brit. Trilob., p. 122, pl. x, figs. 1, 2.
1918. *Homalonotus* (*Burmeisterella*) *elongatus* Reed, Geol. Mag., pp. 314, 325.

The pygidium on which this species was founded was sufficiently described by Salter (op. cit.).

The species has been chosen by the present author as the type of his new subgenus *Burmeisterella* (op. cit. supra), and its affinities have been discussed. It is unfortunate that no further examples of the species have been recognized, and that we are ignorant of the thorax and head-shield, though apparently Salter believed that the fragments figured by Phillips[4] belonged to it. But this conclusion seems to me to be extremely doubtful after a careful examination of the actual specimens in the Jermyn Street Museum. ($\frac{2}{2}^{9}$ M.P.G.) ($\frac{2}{3}^{9}$ M.P.G.)

Locality.—Meadfoot, Torquay.

Horizon.—Meadfoot Beds.

[1] Koch, op. cit., t. i, figs. 3, 3*a*.
[2] Reed, Geol. Mag., 1918, pp. 314, 324, 325.
[3] Ussher, Mem. Geol. Surv., Explan. Sheet 350, 1903, p. 35.
[4] Phillips, Palæoz. Foss. Cornw. Devon, 1841, p. 130, pl. lvii, figs. 253*a–e* (*H. Knighti* (?), figs. 253*a–c*; *H. Herscheli* (?), fig. 253*d*).

Homalonotus (*Burmeisterella*) *armatus* (Burmeister) ?

1843. *Homalonotus armatus* Burmeister, Organ. Trilob., p. 102, pl. iv, fig. 1.
1883. *Homalonotus armatus* Koch, Abh. Geol. Spec. Kart. Preuss., iv, 2, pp. 12–17, t. i, figs. 1–6.
1909. *Homalonotus* (*Burmeisteria*) *armatus* Gürich, Leitfossilien, Lief. ii, Devon, p. 156, t. xlviii, fig. 2.

It is doubtful if this species really occurs in England, but the material from Meadfoot is too poor to decide the question. Fragmentary thoracic rings and portions of the pygidium from the tough brownish sandstone of Meadfoot which are preserved in the Sedgwick Museum (S. 5) appear to possess the characters described and figured by Koch (op. cit.). They seem certainly distinct from *H. Champernownei* of the red argillaceous beds of the New Cut.

Horizon.—Meadfoot Beds (sandstone).

Locality.—Meadfoot, Torquay (S. 5).

Homalonotus (*Burmeisterella*) sp.

There is in the Sedgwick Museum one left free cheek, somewhat distorted, from the New Cut, Torquay, which has the peculiarity of the border being raised and sharply bevelled so as to form an angulated edge. In this respect it agrees with the cheek figured by Drevermann[1] as *Homalonotus* sp. from the Lower Coblenzian of Oberstadtfeld, and in describing it this author remarks that the possession of this border separates it from all other species of the genus. In our specimen, which is complete except for the posterior margin, the general surface of the cheek is swollen and elevated near the eye but sinks down into a broad concentric submarginal concavity which rises to the sharply angular inner edge of the border; the latter increases in width to the genal angle, and has a bevelled outer face. There is the base of a large, stout, rounded spine or tubercle near the inner edge of the swollen portion of the cheek, as in Drevermann's figure. A more quadrate, less perfect free cheek from the same locality at Torquay is also preserved in the Sedgwick Museum, and resembles the other figure (fig. 1) given by Drevermann of this undetermined species. The presence of the spine-base on the cheek suggests that it belongs to the subgenus *Burmeisterella*, and probably one of the species above described should receive it.

Horizon.—Red Beds (Staddon Grits).

Locality.—New Cut, Torquay (S. 9, 100).

Homalonotus (*Parahomalonotus*) *Whidbornei* sp. nov. (Pl. IV, Fig. 4.)

Definition.—General shape elongated, flattened; trilobation nearly obsolete. Head-shield short, broadly subtriangular, truncated in front in middle (with a small median epistomal point projecting below ?). Epistomal sutures on upper surface of head-shield

[1] Drevermann, *Palæontographica*, xlix, 1902, p. 74, t. ix, figs. 1, 2, 3 (?).

parallel and in continuation of anterior branches of facial sutures, cutting front margin at right angles and bounding on each side broad flattened band forming a prora equal in width to pre-glabellar area, from which it is cut off by a gently concave transverse suture. Middle-shield broadly subtriangular, truncated in front by transverse suture, with subrectangular anterior lateral angles projecting forwards, and situated apart about one and a half times the front width of the glabella. Facial sutures with anterior branches curving in strongly from the eyes and then running straight forwards parallel to each other to pass into epistomal sutures in the same line; posterior branches bending suddenly outwards behind eyes parallel to posterior edge of head-shield. Glabella scarcely elevated, subrhomboidal, wide at base, but narrowing at about half its length to a truncate anterior end, about two-thirds the length of the head-shield and one-third its width at base. Axial furrows shallow. Pre-glabellar area gently concave, about one-fourth the length of the glabella. Occipital ring well marked, gently rounded, with meso-occipital portion wider in middle than pleuro-occipital portions. Occipital furrow strong, arched slightly forwards at base of glabella. Eyes small, slightly elevated, situated at about half the width of the glabella from its side and at about half its length. Fixed cheeks flattened, but rising to slight convexity at eyes. Free cheeks slightly convex in region of eyes (marginal portion unknown).

Thorax much flattened, with lateral portions almost horizontally extended, composed of thirteen segments; axis very wide, only marked off from pleural lobes by slight constriction of segments and by faint depression on surface. Pleuræ subcylindrical, flattened (ends not preserved), with narrow submedian pleural furrow well marked.

Pygidium semicircular? Axis very broad at front end, conical, rapidly tapering behind, composed of eight to nine complete rings. Lateral lobes not well preserved.

Dimensions (34–6 T.):—

		mm.
Length of head-shield		28
Length of glabella		17
Distance from anterior end of glabella to front margin of head-shield (= pro-glabellar area + prora)	*c.*	7
Width of glabella at base	*c.*	22
Width of glabella at front end	*c.*	14
Distance of eye from posterior margin of head-shield	*c.*	8
Distance of eye from side of glabella	*c.*	7
Length of thorax		40
Length of axis of pygidium		17
Width of axis at front end	*c.*	19

Horizon.—Meadfoot Beds.

Locality.—Field at back of Kilmorie, near Hope's Nose, Torquay ($\frac{34}{6}$ T).

Remarks.—The single specimen of this trilobite is in the Torquay Museum (Tablet 34–6); it is not in a good state of preservation, and

it is difficult to make out the characters of the front of the head-shield, the left-hand side of which is missing as well as the greater part of the free cheek and lateral margin of the right side. The ends of the thoracic pleuræ are also broken off, and the lateral lobes of the pygidium are not preserved. The whole specimen has also been flattened out by pressure, but it seems that it naturally possessed an almost complete absence of transverse convexity, and that the trilobation was indistinct or nearly obsolete. The affinities of the species seem to lie with that group of species of the subgenus *Parahomalonotus*[1] which comprises *H. lævicauda* Quenst.,[2] *H. planus* Sandb., and *H. obtusus* Sandb., as defined by Koch (op. cit.). The pygidium from the "Hauptquartzit" figured by Kayser[3] as *H. multicostatus* Koch, appears to bear a close resemblance to our specimen.

Dalmanites (*Asteropyge*) *laciniatus* (Roemer).

1844. *Cryphæus laciniatus* F. Roemer, Rhein. Uebergangsgeb., p. 82, t. ii, fig. 8.

1889. *Cryphæus laciniatus* Kayser, Abh. k. preuss. geol. Landesanst., N.F., Heft i, p. 88, t. xxiv, figs. 1–8 (? 9, 10).

In the Sedgwick Museum there is the impression of the left half and posterior end of a somewhat distorted pygidium (S. 1) from the Red Beds of the New Cut, Torquay, which precisely agrees with Kayser's definition and figures of the common form of "*Cryphæus*" *laciniatus* Roem., from Daleiden. The five lateral spines and the much broader, but shorter, flattened, sublanceolate median posterior spine are well seen, though the first lateral spine is almost entirely broken off in our specimen. Another smaller example in the same collection and from the same locality has lost the first two spines on the left side, but shows the whole posterior part of the pygidium, including the lateral lobe and last spine of the right side. The characters of the axis and pleuræ agree with Kayser's definition. There is also one fairly well preserved head-shield (S. 2) in the Sedgwick Museum, likewise from New Cut, showing the eyes, glabella, and part of the right cheek, and another left free cheek (somewhat crushed), with the genal spine attached. The number of rows of lenses in the eye in this specimen is about 27, and none of the rows appear to consist of more than eight lenses. These fragments of the head-shield do not differ from Kayser's description of the common form of the species, but much confusion has arisen from the different applications of the specific name *laciniatus*, so that it is necessary to limit the synonymy which is frequently given. Probably the trilobite from Torquay, which Salter[4] termed *Phacops* (*Cryphæus*) *punctatus* (Stein.), should be referred to this species, but on the other hand the specimens from Liskeard which he figured

[1] Reed, Geol. Mag. 1918, p. 326.
[2] Koch, op. cit., p. 55, t. viii, figs. 1–7.
[3] Kayser, Abhandl. geol. preuss. Landesanst., N.F., i, 1889, p. 80, t. xi, fig. 2.
[4] Salter, Mon. Brit. Trilob., 1864, p. 59.

under this name seem to belong to Kayser's species *Lethæa*.[1] The form from North Devon which Whidborne[2] described as *Dalmanites* (*Cryphæus*) *laciniatus* var. *occidentalis* is quite distinct from our Torquay specimens. The use of the subgeneric name *Asteropyge* in place of *Cryphæus* is here adopted.[3]

Dimensions.—*Pygidium* (S. 1): length, (I) *c.* 17 mm., (II) *c.* 9 mm.; width (I) *c.* 20 mm., (II) *c.* 11 mm. *Head-shield* (S. 2): length, 8 mm.; width, *c.* 18 mm.

Horizon.—Red Beds (Staddon Grits).

Locality.—New Cut, Torquay (S. 1, 2).

Beyrichia (*Zygobeyrichia*) *devonica* (Jones & Woodward).

1889. *Beyrichia devonica* Jones & Woodward, Geol. Mag., p. 386, Pl. IX, Figs. 3*a*-3*d* (? 4, 5).

1916. *Zygobeyrichia devonica* Ulrich, Prof. Paper 89, U.S. Geol. Surv., p. 291, pl. xxvii, figs. 1–6.

The species *Beyrichia devonica*, which was first described by Jones and Woodward from the New Cut, Torquay, has been recently recorded from the Chapman Sandstone (Lower Devonian) of Maine by Ulrich (op. cit.), who selects it as the type of a new genus, which he calls *Zygobeyrichia*, characterized "by the partial or complete obsolescence of the posterior lobe and by the excessive development of the ventral junction of the median and anterior lobes". It may be questioned whether this should not denote subgeneric rather than generic rank. The type-specimens of the species are in the Sedgwick Museum.

Horizon.—Red Beds (Staddon Grits).

Locality.—New Cut, Torquay. (S. 89.)

EXPLANATION OF PLATE IV.

Fig. 1.—*Homalonotus* (*Burmeisterella*) *bifurcatus* sp. nov. Head-shield. × 1½. Staddon Grits: New Cut, Lincombe Drive, Torquay. (Sedgwick Museum.)

Fig. 2.—Ditto. Pygidium of same specimen. × 1½. (Sedgwick Museum.)

Fig. 3.—Ditto. Impression of same pygidium, showing terminal spines. × 1½. (Sedgwick Museum.)

Fig. 4.—*Homalonotus* (*Parahomalonotus*) *Whidbornei* sp. nov. Nat. size. Meadfoot Beds: field at back of Kilmorie, near Hope's Nose, Torquay. (Torquay Museum.)

On the Geology of Castle-an-Dinas Wolfram Mine.

By E. H. Davison, B.Sc.

THERE are two hills named Castle-an-Dinas in West Cornwall, one near Penzance and the one on which the Wolfram Mine is situated, which lies about 2 miles east of St. Columb Major and about 4 miles to the north of the St. Austell granite mass.

[1] Kayser, op. cit., p. 86, t. xi, figs. 5, 6.

[2] Whidborne, Quart. Journ. Geol. Soc., vol. lviii, 1897, p. 445, pl. xxxiii, figs. 9–13.

[3] Reed, Geol. Mag., 1905, pp. 173, 225.

The hill rises 700 feet above sea-level, and forms a conspicuous feature in the landscape; it is surmounted by an ancient earthwork which has given the hill its name. In 1915 the outcrop of a lode was traced on the northern slope of the hill, and this has been developed by mining operations and yields a remarkably clean wolfram ore.

Geological Structure of the District.

In a paper read before the Royal Geological Society of Cornwall [1] the writer described the general geology of the district, but since then the development of the mine has been carried further and fresh light has been thrown on the geological structure of Castle-an-Dinas hill.

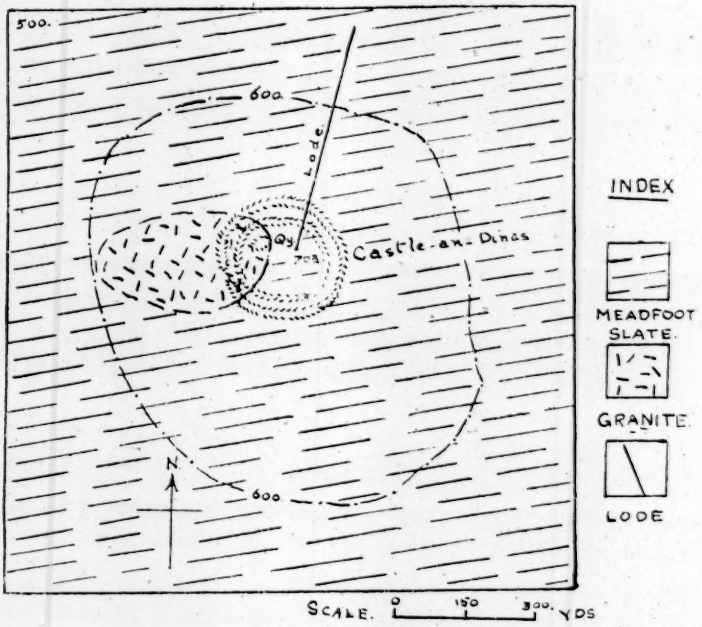

Fig. 1.—Sketch-map of Castle-an-Dinas.

The hill is mainly built of Meadfoot Slates, which strike approximately east and west, and are folded on axes roughly parallel to the strike. The hill lies within the metamorphic aureole of the granite, and the slates have in addition been subjected to intense pneumatolytic alteration, as a result of which the contact minerals have been almost completely destroyed; in one case, however, the slates were seen to contain wollastonite.

[1] "The Geology of Castle-an-Dinas and Belowda Beacon": Proc. R.G.S. Corn., vol. xix.

The result of the pneumatolytic alteration is a rock consisting essentially of quartz and tourmaline with some white mica and iron oxide, in which the cleavage, slip-cleavage, and folding of the original slate have been preserved. Under the microscope the slate is seen to be composed of layers of tourmaline needles, alternating with layers of clear quartz, the tourmaline layers containing mica and iron oxide. The slate maintains this character close up to the lode walls, though specimens collected from the neighbourhood of the lode fissure were seen to contain fine grains of cassiterite.

On the summit of the hill the slate is penetrated by a granitic rock, which, as exposed on the hill-top, has the appearance of a granite-porphyry. On tracing the outcrop to the west, down the hill-side, it has a more normal granitic character, but nowhere is it a coarsely crystalline granite such as occurs on Belowda Beacon to the east. The granite outcrop and that exposed in the mine workings seem to be in the nature of apophyses of the Belowda mass to the east.

On the south of the hill a quartz-porphyry dyke traverses the slate with a strike almost east and west, and a south underlie. The rock is highly tourmalinized, and has been worked for its tin contents.

The Castle-an-Dinas Lode.

The lode outcrops on the north side of the hill with a strike of 15° E. of N. It is a practically vertical fissure in the slate, and is at present being worked by two adits driven into the hillside at an interval of about 10 fathoms. The width of the lode varies from a few inches to about 3 feet, but an average width of about 2 feet is maintained with fair regularity.

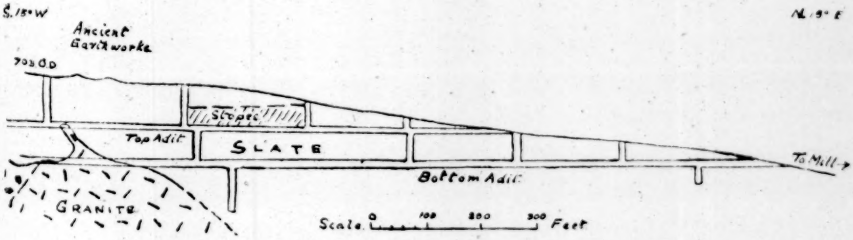

Fig. 2.—Section of workings, Castle-an-Dinas Mine. From plan lent by Mr. J. Chenoweth.

The lode-filling consists of white vein quartz with irregularly distributed patches and strips of very coarsely crystallized wolfram, the patches having a diameter of a few inches up to 2 feet or so. A remarkable character of the lode-filling is the almost complete absence of minerals other than quartz and wolfram. Occasional copper stains are seen and there is a little native copper but only

in insignificant amounts. There is almost complete absence of tin, the ore concentrates containing less than 0·3 per cent. The country rock, on the other hand, is seen under the microscope to contain cassiterite, and samples taken from the slate in the neighbourhood of the granite have been assayed and found to contain as much as 1 per cent. These values are, however, too inconsistent to have any economic importance. Another remarkable character is the absence of tourmaline in the lode material, while the country rock is highly tourmalinized.

Towards the far end of the upper level the eastern wall is formed of a granitic rock much decomposed, forming white or pink clay enclosing partly decomposed felspar fragments, quartz, flakes of white mica, and needles of tourmaline. There are also harder bands of greisen composed of quartz, pale brown mica, which contains lithia and is very strongly birefringent, and topaz, with grains and needles of tourmaline.

In the lower level at the point indicated in the section (Fig. 2) granite appeared in the floor of the lode in the form of a soft clay, containing grains of quartz and flakes of muscovite. This rose slowly towards the south, and passed into a hard fine-grained granite, which extended above the roof of the level. On driving a cross-cut west, the base of the granite was seen in the floor where it was underlain by clay-slate, and on continuing the level to the south the slate again appeared above the granite, the surface of the latter continuing with undulations. A winze has been sunk 120 yards north of the point where the granite first appears, but though driven to a depth of 87 feet no granite was met with. These facts point to the granite having an irregular tongue-like form rather than to its being a portion of the main mass.

Development is not sufficiently advanced to show if the lode continues down into the granite, but there are irregular patches of quartz with wolfram in the granite tongues, and it seems probable that the lode fissure was only deflected by the presence of the harder rock. It does not, however, follow that the lode-filling maintains the same character.

The intimate way in which the granite penetrated the clay-slate can be seen in specimens of clay-slate collected from points in the levels where no granite is in sight; these are seen to be traversed by fine veins of granitic material which cut across the foliation and vary from an inch or so to less than one-sixteenth of an inch in width. Under the microscope these fine veins are seen to consist of clear quartz, pale brown, highly birefringent mica and tourmaline, with occasional grains of cassiterite.

The Castle-an-Dinas lode is almost unique in character when compared with other lodes of West Cornwall. It is characterized by the following points:—

1. The absence of pneumatolytic minerals such as tourmaline, fluorspar, and topaz from the lode contents.

2. The absence of sulphides and the very small proportion of cassiterite present.

3. The remarkably coarse texture of the lode-filling.

The veins of the Kit Hill Mine, Callington, are in some respects similar in character, but they differ in containing cassiterite, tourmaline, and mispickel; they also occur just below the surface of the granite and not in the clay-slate. There is also some similarity in the veins of the Hemerdon Hill stockwork, which are like those of Kit Hill, with a much smaller proportion of mispickel in the veins, which also contain scorodite. There is again a similar veinstone in the middle lode of the recently reopened Killifreth Mine, St. Day, in which coarse patches of wolfram occur in clear quartz, which is also traversed by veins carrying cassiterite, blende, and mispickel.

The Castle-an-Dinas lode seems to represent the results of mineral deposition in the upper part of the tin and tungsten zone, the sequence of events having been somewhat as follows:—

1. Folding and cleaving of the clay-slate.

2. Intrusion of granite followed by pneumatolytic action, which resulted in the tourmalinization of the slate and the formation of greisen, kaolinized granite, and deposition of cassiterite in the slate.

3. The opening of the lode fissure.

4. Filling of the fissure by means of hot solutions or pegmatite-like intrusions.

On Jurassic Ammonites from East Africa, collected by Prof. J. W. Gregory

By L. F. Spath, B.Sc., F.G.S.

(*Concluded from p. 320.*)

Genus Sowerbyceras Parona & Bonarelli.

Sowerbyceras aff. *tortisulcato* d'Orbigny sp. (Pl. I, Figs. 5*a–c*.)

1870. *Phylloceras* n.sp. aff. *tortisulcato* (d'Orbigny) Neumayr, "Jurastud. III, Die Phylloc. Dogger Malm," p. 345, pl. xvii, fig. 9.

1895. *Ph. subtortisulcatum* (Pompeckj ?) Parona, Nuove osservaz. s. l. fauna e l'età degli strati con *Posidonomya alpina* nei Sette Communi Pal. Ital., vol. i, p. 10.

1897. *Ph.* sp. aff. *tortisulcatum* (d'Orbigny), Hochstetter, "Die Klippe St. Veit bei Wien," Jahrb. kk. R.A., vol. xlvii, pt. i, p. 142.

1897. *Sowerbyceras Neumayri* Parona & Bonarelli, "Sur la Faune Callov. Infér. Savoie": Mém. Acad. Sc. Savoie, ser. 4, vol. vi, p. 120.

Dimensions.—Diameter	. .	15 mm.
Height of the last whorl	. .	53 per cent of the diameter.
Thickness	. .	46 ,, ,, ,,
Umbilicus	. .	18 ,, ,, ,,

Description.—This specimen is characterized by a subrectangular whorl-section with depressed venter, which is peculiar to Fontannes's

group of "*Phylloceras*" *tortisulcatum*. The greatest thickness of the whorls is near the umbilical margin, but the sides are almost parallel and the ventral area is evenly convex, not flattened. The ratio of height to thickness is about 7 : 6, as compared with 4 : 3 in *Sowerbyceras tortisulcatum*, according to Pompeckj,[1] and with 8 : 7 at most in *S. protortisulcatum* Pompeckj sp. The umbilicus is comparatively large and deep; its walls are rounded and not abrupt. There are about four constrictions to the whorl, beginning as conspicuous grooves with a forward bend at the umbilicus, but becoming less distinct on the lateral area. After bending back again they become once more pronounced, passing across the periphery with a sinus that is concave forwards.

The suture-line consists of very distinctly diphyllic external, first and second lateral saddles, and of monophyllic auxiliary saddles. This type of suture-line is well illustrated in de Loriol's [2] figure of that of *S. tortisulcatum* d'Orbigny sp.[3] (which he calls a species of the *Renggeri* Marls), and in that of *S. helios* Noetling,[4] though here the saddles, perhaps, are drawn so as to appear too plump. There are seven auxiliary lobes and saddles, but the inner of these are merely denticulations, though present already at a diameter of 9 mm. This number agrees with that of the auxiliary lobes in the three Callovian species, *S. antecedens* (Pompeckj),[5] *S. transiens* (Pompeckj),[6] and *S. subtortisulcatum* (Pompeckj).[7] The internal portion of the suture-line consists of six saddles, and it is important to note the monophyllic character of the first lateral saddle (dorsal), which shows the specimen described here to belong to the "Formenreihe" of *Phylloceras tortisulcatum* = *Sowerbyceras*, and not to the group of *Ph. ultramontanum*, as the backward bend of the constrictions of the ventral area would suggest. The internal portion of the suture-line shown in Fig. 5*c* is not drawn from the same part of the specimen as the external half.

Observations.—Pompeckj,[8] when establishing the "Formenreihe" of *Phylloceras tortisulcatum*, stated that the developmental tendencies in this series were as follows: (*a*) increase in the size of the umbilicus from the geologically older to the younger forms; (*b*) change of whorl-section from elliptical to quadrangular, with the greatest thickness of the whorl moving nearer and nearer to the umbilicus; (*c*) increase in the angularity of the constrictions, with a tendency to bend forward a second time on the periphery; (*d*) decrease in the complication of the lobe-line. On account of this last character Pompeckj called the series retrogressive, and he also mentioned that

[1] Loc. cit., Revision, 1893, p. 54.
[2] Loc. cit., 1893, text-fig. 1, p. 5.
[3] d'Orbigny's figure (*Ter. Jurass.*, pl. 189, fig. 3) is probably inaccurate.
[4] *Der Jura am Hermon*, Stuttgart, 1887 pl. ii, fig. 3*c*.
[5] Loc. cit., Revision, 1893, p. 47.
[6] Ibid., p. 51.
[7] Ibid., p. 52.
[8] Loc. cit., Revision, 1893, pp. 40–5.

the monophyllic ending of the first lateral saddle of the dorsal suture was characteristic of this group. On examination of the present specimen it is found that these points do not allow of its immediate placing in the series, for, whereas constrictions and umbilicus point to an early form, whorl-shape and suture-line ally the specimen more with the later species of the series. To judge by specimens of *S. tortisulcatum*, however,[1] the secondary forward convexity of the constrictions (on the periphery) becomes more pronounced only in larger examples, and in young specimens there is only the angular bend on the lateral area, whereas the ventral portions of the sulci are straight. Also the section of the inner whorls is much thicker near the umbilical edge and narrower at the venter than it is in the adult whorls. After attaining a diameter of about 7 mm. the proportions given in Fig. 5*b* appear, and the section gradually changes to the quadrangular shape characteristic of the adult *S. tortisulcatum*, with very square ventral area.

Although, therefore, in the adult *S. tortisulcatum* the proportions are different, the inner whorls are comparable to the specimen collected by Professor Gregory, but the constrictions of d'Orbigny's species show a ventral convexity already at a diameter of 9 mm. The course of the constrictions also separates the East African specimen from *S. protortisulcatum* Pompeckj sp., found by the writer in profusion in the Argovian of Jebel Zaghuan, Tunisia.[2] The whorl-section here is very similar, and the suture-line also agrees very well in general characters, but has a far smaller number of elements. In *S.* cf. *Loryi* Munier-Chalmas sp.,[3] recorded from the same locality, the smaller umbilicus exactly agrees with the specimen under review, but according to Pervinquière [4] the typical specimens of this *acanthicus*-zone ammonite show constrictions only on the body-chamber. This author (after Kilian) also united with *S. Loryi* the ammonite described by Gemmellaro [5] as *Phylloceras silenus* Dumortier & Fontannes. The Sicilian form agrees with the specimen here described in dimensions (Gemmellaro, for a specimen of the diameter of 21 mm., gives the percentages as 51, 44, and 15) and, to a certain extent, in the suture-line, for in a much larger specimen there are only four monophyllic auxiliary saddles, as in the suture-line of *S. protortisulcatum*, given by the writer.[6] A number of forms of *Sowerbyceras* more or less agree with the East African specimen in dimensions and suture-line, but have a different (forward) course of the constrictions, e.g. *S. Tietzei*

[1] Some of the specimens examined belong to the Astier Collection, preserved in the British Museum (Nat. Hist.), and d'Orbigny stated that he had received limonitic specimens of *A. tortisulcatus* from M. Astier (*Ter. Crét.*, p. 164).
[2] Loc. cit., 1913, p. 565.
[3] Ibid., p. 566.
[4] *Études de Pal. Tunis.*, i, Ceph. Ter. Second, 1907, p. 16.
[5] Loc. cit., 1877, p. 185, pl. xvi, fig. 1–3
[6] Loc. cit., 1913, pl. liii, fig. 2c.

Till,[1] *S. ovale* Pompeckj sp.,[2] and others. On the other hand, in the oldest specimen of *Sowerbyceras* figured, the Bathonian *S. Neumayri*, the constrictions are typically angular, and the thinness of that specimen only characterizes it as distinct.

The type of constrictions shown by the specimen here described is found in the group of *Phylloceras ultramontanum* Zittel, and is well illustrated in e.g. *Phylloceras mediterraneum* (Neumayr) in Favre,[3] *Ph. zignodianum* (d'Orbigny) in Vacek,[4] and in *Ph. Fredericiaugusti* Pompeckj,[5] but according to the latter author in this group the first lateral saddle of the internal (dorsal) suture is diphyllic.[6] Also, though the suture-line of d'Orbigny's *A. zignodianus* shows bifid saddles, not unlike those of a *Sowerbyceras*, the quadrate whorl-section of the East African specimen and the absence of the lateral lappet at the angle of the constrictions are against a closer comparison with any of the forms of the group of *Ph. ultramontanum*.

It is probable that the specimen is most nearly related to the older forms of *Sowerbyceras* recorded by Neumayr, Parona, and Hochstetter. The former author mentioned (apart from the specimen from the Bathonian of Mount Crussol, near Valence, Ardèche, referred to above) a fragment from the Klaus beds of Buscecs, Transylvania,[7] as the oldest specimen which can be referred to d'Orbigny's species. Hochstetter recorded from the Klaus beds of St. Veit, near Vienna, very small *Phylloceras*,[8] the curious course of the constrictions of which favoured the assumption that they belong to Pompeckj's " Formenreihe " of *Ph. tortisulcatum*. Parona recorded his specimen (doubtfully referred to *Ph. subtortisulcatum* Pompeckj[9]), together with *Lytoceras adeloides* and other forms of the Upper Bajocian and Bathonian, from the *Posidonomya alpina* beds of the Southern Alps.

Horizon and Distribution.—The group of *Phylloceras tortisulcatum* (d'Orbigny) ranges from the Bathonian up to the Tithonian, but

[1] Op. cit., 1910, p. 260, pl. xvi (1), figs. 12–14.

[2] Op. cit., 1893, p. 48, pl. i, figs. 4 and 5. This species is not included in the genus *Sowerbyceras* by Parona & Bonarelli.

[3] " Descr. Foss. Ter. Jurass. Mont. Voirons (Savoie) " : Mém. Soc. Pal. Suisse, vol ii, 1875, p. 19, pl. i, fig. 10. In this Argovian form the constrictions are far too deep.

[4] Op. cit., 1886, pl. v, fig. 14 only, *non* pl. iv, figs. 8–10.

[5] Op. cit., 1893, pl. i, fig. 12–14.

[6] It may be mentioned that Quenstedt (*Amm. Schwäb. Jura*, p. 762, pl. lxxxvi, and p. 864, pl. xciii) had included in *A. tortisulcatus* both forms put by Pompeckj into the " Formenreihe " of *Phylloceras ultramontanum*, also typical *Sowerbyceras*. The writer is not inclined to lay too much stress on the course of the constrictions shown to be variable in many other *Phylloceras*. On the other hand, *Sowerbyceras* is probably a descendant of the Bajocian *ultramontanus* group, as Parona & Bonarelli (loc. cit., p. 117) suggested.

[7] Loc. cit., 1870, p. 345.

[8] Loc. cit., 1897, p. 142.

[9] De Loriol (loc. cit., 1900, p. 18) was doubtful about the justification of the separation of *Ph. subtortisulcatum* Pompeckj from the typical *Ph. tortisulcatum* d'Orbigny sp.

according to Kilian [1] does not persist into the *Boissieri* beds of the lowest Neocomian. The type itself is Callovian and of wide distribution, both in the Alpine-Mediterranean region, as far as the Caucasus, but (with related forms) also in Wurtemberg.

Locality.—No. 10, from the grey, otherwise unfossiliferous limestone, beside the break-pressure tank, mile $\frac{11}{11}$ on the Mombasa Pipe-line (together with *Phylloceras* cf. *disputabile* Zittel).

Genus Protetragonites Hyatt.

Hyatt [2] created this genus for *Lytoceras quadrisulcatum* d'Orbigny sp., a form that is very abundant in the Lower Valanginian,[3] though similar ammonites occur in the Tithonian.[4] Vacek [5] traced the group of *L. quadrisulcatum* back to his Bajocian *L. rasile*, and included [6] in the same group *L. rubescens* Dumortier sp. and *L.* n.sp. ind.,[7] which forms are assigned to the genus *Megalytoceras* S. Buckman by its author.[8] Vacek remarked that the Tithonian *Lytoceras municipale* Oppel sp. was so near to *L. rasile* that in spite of the enormous chronological separation one might almost be inclined to consider them specifically identical. The writer is not convinced that the Tithonian–Neocomian *quadrisulcatus* group (= *Protetragonites* s.str.) can be traced back even to the Bathonian *L. tripartitum* Raspail sp., and, in fact, considers the latter to require a new generic name since its suture-line alone clearly distinguishes it from the other Lytocerata. Owing, however, to lack of material and consequent inability either to prove the independence of this group with the necessary precision, or to trace its relations to such forms as *L. rasile* Tornquist *non* Vacek,[9] *L. tripartitiforme* Gemmellaro, etc., the specimen to be described here is provisionally referred to the genus *Protetragonites*.

Protetragonites cf. *tripartitus* Raspail sp. (Pl. I, Figs. 6*a–c*.)

1829. *Amm. tripartitus* Raspail, Ann. Sci. Obs. (Lycé, 1831), pl. xi, fig. 5, pl. xii, fig. 7.
1841. *A. quadrisulcatus* d'Orbigny, Ter. Crét., p. 151, pl. xlix, fig. 3.
1842. *A. tripartitus* (Raspail), d'Orbigny, Ter. Jurass, p. 496, pl. 197, figs. 1–4.
1846. *A. polystoma* Quenstedt, Cephalopoden, pl. xx, fig. 8.
1860. *A. tripartitus* (Raspail), Ooster, Cat. Ceph. foss., p. 66, pl. xvii, figs. 1–3.

[1] *Lethæa geognostica*, ii, Mesozoicum, vol. iii, Kreide, pt. i, Unterkreide, fasc. 2, 1910, p. 171.

[2] In Zittel's *Text-book of Palæontology*, edited by C. R. Eastman, vol. i, pt. ii, 1900, p. 569.

[3] See e.g. Kilian, *Lethæa geognostica*, ii, Mesozoicum, vol. iii, Kreide, pt. i, fasc. 2, 1910, p. 174.

[4] Ibid., p. 171, and Sayn ("Amm. Pyrit. Marnes Valang, S.E. France": Mém. Soc. Géol. France, Pal., No. 23, 1901, p. 2) identifies his Valanginian specimens with Zittel's Tithonian ammonites.

[5] Loc. cit., 1886, p. 64.

[6] Ibid., p. 60.

[7] Ibid., p. 64, pl. i, figs. 6, 7.

[8] "On certain Genera and Species of Lytoceratidæ": Q.J.G.S., vol. lxi, 1905, p. 151.

[9] Loc. cit., 1898, p. 28 (160), pl. v, fig. 8.

1866. *A. tripartitus* (Raspail), Benecke, "Üb. Trias u. Jura i. d. Süd-Alpen"; Geogn. Pal. Beitr., p. 175.
1891. *Lytoceras tripartitum* (Raspail), Haug, "Les Chaînes subalp. entre Gap et Digne": Bull. Serv. Carte Géol. France, vol. iii, p. 79.
1897. ,, ,, ,, Hochstetter, "Die Klippe v. St. Veit, b. Wien": Jb. k.k. R.A., vol. xlvii, Hft. i, p. 143.
1905. ,, ,, ,, Simionescu, "Üb. Alt. Klaus-Schichten Süd. Karpathen": Verh. k.k. R.A., No. 10, p. 212.

Description.—This fragment, consisting of two cameræ only, is about 7 mm. in length. There is very little difference in the dimensions of the two terminal (septal) surfaces, so that the coiling must have been extremely slow. The thickness of the whorl is nearly equal to the height, which latter is 4·5 mm. The section, however, is not circular, but compressed, and the dorsal furrow is very shallow, indicating contact with (but not inclusion of) the inner whorls. The fragment, fortunately, shows a constriction, with a forward bend on the side and a backward sinus on the periphery.

The suture-line consists of very few elements, namely, a very long but narrow external (ventral) lobe, a bifid external saddle, about the size of the (equally bifid) lateral lobe, and slightly larger than the (also bifid and similar) lateral saddle.[1] The second lateral lobe is shorter than the first lateral lobe (which, itself, is shorter than the external lobe), and after the very simple and almost entire second lateral saddle there only is a very small auxiliary lobe, followed by a broad and more or less entire umbilical saddle. In describing the almost identical suture-line of *A. tripartitus* (Raspail) d'Orbigny[2] apparently had regarded this auxiliary lobe as merely an indentation in the second lateral saddle ("auxiliary saddle" in d'Orbigny), but the continuation of the suture-line on the dorsal side shows it to be a true third lobe. The deep internal lobe is flanked by two long and monophyllic saddles. The "cross"[3] characteristic of the group of *Lytoceras fimbriatum* (in a wider sense, not only *Fimbrilytoceras* S. Buckman) is not very pronounced. The septa are rather distant (there are only three in the space of 7 mm.), and they do not interpenetrate.

Observations.—The fragment differs in section from the type-figure, and especially from the compressed examples, such as that figured by Quenstedt as *A. polystoma*, by having the thickness nearly equal to the height of the whorl. This probably is not due only to the small size of the present specimen, nor to the fact that the typical specimens of *P. tripartitus* are generally (elliptically) compressed. In examples of this species from the Bathonian of the South

[1] In fig. 6c the first lateral saddle is drawn just a shade too slender. On account of the smallness of these specimens collodiotypes could not be taken.
[2] Loc. cit., Ter. Jurass., 1842, p. 497.
[3] See Pompeckj, loc. cit., Revision, 1893, text-fig. 24 on p. 115.

of France [1] at a whorl height of 3·75 mm. the thickness amounts to 3·25 mm. and the ratio increases to 8·75 : 6·25 mm. Further, in the typical specimens the constrictions begin with a more decided forward bend from the umbilicus. On the other hand, there is almost perfect agreement in the suture-line, both external and internal; so that even if the East African specimen cannot be identified with *P. tripartitus*, it, at any rate, must belong to a closely related form.

Lytoceras tripartitiforme Gemmellaro,[2] which also occurs associated with *Phylloceras Kudernatschi* Hauer sp., *Ph. disputabile* Zittel, and other forms of the Klaus Beds, is distinguished from the specimen here considered by the different course of the constrictions. This difference also separates the East African example from *L. polyhelictum* (Boeckh), a form of the *Parkinsoni* zone of Hungary and Daghestan, and considered to be near to *P. tripartitus* by Neumayr et Uhlig.[3] The whorl-section of *L. polyhelictum* is more like that of the present specimen than is the compressed shape of *P. tripartitus*; on the other hand, the three saddles shown in the suture-line of the Daghestan form, given by the latter authors, are different from those shown in Fig. 6*c*.

Lytoceras polyanchomenum Gemmellaro,[4] from the *macrocephalus* beds of Sicily but recorded also from the Swiss Oxfordian,[5] may agree with the specimen here examined in whorl-section and possibly in the constrictions,[6] but the suture-line of the East African specimen certainly does not show the lateral branch of the dorsal lobe continued on to the lateral area.

Horizon and Distribution.—*P. tripartitus* is a very common ammonite in the zones of *Oppelia fusca* and *Zigzagiceras zigzag* (Bathonian) in the South of France,[7] and also occurs in the Bathonian of Italy, Switzerland, Austria, and the Carpathians. Hochstetter [8] records the species even from the Lower Bajocian, but his specimens were badly preserved, and on the following page of the work quoted he calls *P. tripartitus*, "of the Bathonian, a younger form of the group of *Lytoceras quadrisulcatum*." He recorded [9] sixty-five specimens from the Bathonian of St. Veit, and added that Griesbach already had called this species "abundant and easily identifiable,

[1] There were no specimens available for comparison, but the writer was immediately supplied (through the kindness of M. Stuer, of Paris) with three prototypes of Raspail's from Aix (see Haug, loc. cit., 1908, p. 1022) and four specimens from Chaudon, Basses-Alpes (ibid., p. 1023).

[2] Loc. cit., 1877, p. 135, pl. xix, fig. 9.

[3] Loc. cit., 1892, p. 39, pl. iii, fig. 2*a–d*.

[4] Loc. cit., 1872, p. 14, pl. iv, figs. 2, 3.

[5] Favre, "Descr. Foss. Terr. Oxf. Alp. Frib.": Mém. Soc. Pal. Suisse, vol. iii, 1876, p. 35.

[6] According to Gemmellaro's description, not the figures cited. Pl. iii, fig 3, in Favre (loc. cit.) is very near, being the young.

[7] Haug, loc. cit., 1908, pp. 1019–53.

[8] Loc. cit., 1897, p. 109.

[9] Ibid., p. 143.

common also in the Bathonien Inférieur of France". Kilian,[1] however, mentions the species from the Bajocian again and states that Lory had found it with *A. lunula*. It seems possible that *P. tripartitus* or a mutation of that form may go up into the Callovian, but the records of the higher horizons are by older authors, e.g. Quenstedt,[2] Pictet,[3] and Studer,[4] and no mention is made of *P. tripartitus* in the many modern descriptions of Callovian faunæ, in which, on the other hand, *Lytoceras adeloides* is almost universally present. At any rate, Raspail's species is so abundant in the Bathonian of the South of France, that Repelin [5] even speaks of a "zone of *Lytoceras tripartitum*".

Locality.—No. 550, Mwachi River, Pipe-line Crossing, about $\frac{30}{0}$. (Together with *Phylloceras* cf. *Kunthi* Neumayr and *Hecticoceras* sp. juv.)

Genus Hecticoceras Bonarelli.

The specimen described here is an undoubted Oppelid, but its reference to the genus *Hecticoceras* is somewhat doubtful. Its association with Ammonites that are comparable with Bathonian species suggests affinity with those Bathonian Oppelids that have been put into *Hecticoceras* by e.g. Haug, Popovici-Hatzeg, and Parona. These forms, on the one hand, seem to be allied to some of the normal evolute "*Œcotraustes*" of the *Parkinsoni* and *fusca* zones, but not to the early *Œcotraustes*, such as that figured by Vacek,[6] which has a different suture-line. On the other hand, they probably develop into such more or less involute forms of the *macrocephalus* beds as *Oppelia pleurocyma* Parona & Bonarelli,[7] or as *Oppelia subdisca* d'Orbigny sp.[8] These forms have been confused with the earlier and similar *Oppelia* of the *fusca* type, and with *Oxycerites*, groups that are involute and already have a highly specialized suture-line in the Bathonian. To separate, however, the development here indicated from the later and similar

[1] *Montagne de Lure*, Paris (Masson), 1889, p. 79.

[2] *A. polystoma* Quenstedt is recorded from a "black limestone of *macrocephalus* age" from Barrème.

[3] This author (*Traité de Pal.*, vol. ii, 1854, p. 698) stated that *A. tripartitus* was characteristic of the Callovian in France, and was found in Germany, together with *A. Murchisonæ*.

[4] In *Geologie d. Schweiz*, 1853, vol ii, p. 45, *A. tripartitus* is recorded as occurring, with *Phylloceras zignodianum* and *Macrocephalites*, in the Callovian, but on p. 52 it is associated with *S. tortisulcatum*, *Ph. tatricum*, and also *A. plicatilis*, and put into the Oxfordian.

[5] "Jurass. Chaîne Nerthe et l'Étoile": Bull. Soc. Géol. France, ser. III, vol. xxvi, 1898, p. 520. *Ph. mediterraneum* and *Oppelia* here occur with *P. tripartitus*.

[6] Loc. cit., 1886, pl. ix, fig. 13. S. Buckman ("Certain Jurassic Species of Amm. and Brach.": Q.J.G.S., vol. lxvi, 1910, p. 96) is inclined to put this as low as the *discites* zone.

[7] Loc. cit., 1897, p. 129; pl. iii, fig. 1.

[8] Loc. cit., Ter. Jurass., p. 421, pl. 146, and Favre, "Contrib. à l'Étude des *Oppelia*": Mem. Soc. Pal. Suisse, vol. xxxviii, 1912, p. 31.

Lunuloceras[1] would be open to objections from etymological reasons, for *A. hecticus* itself would then be a *Lunuloceras*. In any case the definite relations of the many forms referred to the genus *Hecticoceras* remain yet to be worked out, also the connexion with *Oppelinæ* below and the *Ochetoceras–Trimarginites* fauna above.

Hecticoceras sp. juv. (Pl. I, Fig. 7*a–c*.)

Compare :—

1905. *Hecticoceras Haugi*, Popovici-Hatzeg, "Les Céph. Jurass. M. Strunga" : Mém. Soc. Géol. France, Pal., No. 35, p. 18, pl. iv, fig. 3, pl. v, figs. 2-10.

Dimensions.—Diameter . . 8·3 mm.
Height of the last whorl . . 40 per cent of the diameter.
Thickness . . 32 ,, ,, ,,
Umbilicus . . . 30 ,, ,, ,,

Description.—This specimen represents only the inner whorls of a larger ammonite since it is septate throughout. The periphery shows a keel only on the last two-thirds of the outer whorl, and the earlier portion of the shell is perfectly smooth, with flat sides and a rounded venter. The open umbilicus has steep but rounded walls. The ornament which is shown near the end of the shell (in the form of about six costæ) is distinct near the periphery only ; and only one or two of these obscure folds seem to be very indistinctly continued, with a lateral forward bend, on the sides, though they do not reach the umbilical border. There is an indication near the end of the specimen of a differentiation of the periphery into lateral zones (on each side of the keel) marked off from the sides by an edge, whereas on the previous portion of the last whorl the ventral area is rounded and gradually passes into the sides.

The suture-line consists of a deeply forked, trifid principal lobe, much deeper than the external and second lateral lobes, of irregularly bifid external first and second lateral saddles, and of three auxiliary lobes, slightly raised towards the umbilicus.

Observations.—The suture-line of this specimen is very similar to that of a young *Lunuloceras*, and agrees in all essentials with that of "*Harpoceras*" *lunula* (Zieten) given by Noetling,[2] or with the suture-lines of a number of specimens of this almost universal species-group from many different localities. On the other hand, the suture-line of young Oppelids from the *zigzag* hemera of Powerstock Station, Dorset, is also very similar to that of the specimen here described, as is that given for *Oppelia subradiata* (Sowerby) var A. by Favre.[3] With a very immature specimen it is a matter of opinion whether it should be considered as allied to the Bathonian

[1] Tsytovitch ("Le genre *Hecticoceras*" : Mém. Soc. Pal. Suisse, vol. xxxvii, 1911) has again drawn attention to the difficulty of separating *Hecticoceras* and *Lunuloceras* on purely morphological grounds.

[2] *Der Jura am Hermon*, 1887, p. 18, text-fig. 3.

[3] Loc. cit., 1912, fig. 1 on p. 13.

Hecticoceras[1] rather than to other contemporaneous Oppelids. It should be pointed out, however, that the East African specimen might equally well represent the inner whorls of such Callovian *Lunuloceras* as those figured by Quenstedt,[2] Waagen,[3] Till,[4] Tsytovitch, etc., or even of such Oxfordian and Argovian forms as those figured by de Loriol[5] and Noetling.[6] As has been pointed out before, its affinity with the Bathonian forms of the type of "*Oppelia*" *bisculpta* Oppel sp. = *A. Henrici* Kudernatsch *non* d'Orbigny[7] is suggested only by the associated ammonites.

Hecticoceras Haugi, Popovici-Hatzeg, has a narrower umbilicus in the adult, and the whorl-section, then, also differs considerably,[8] but the young probably comes very near to the specimen here examined. On the other hand, the suture-line appears to be more complex in the Roumanian specimens.

Horizon.—*Hecticoceras*, comparable to the East African specimen, occur in the Bathonian as well as the Callovian.

Locality.—No. 550, Mwachi River, Pipe-line Crossing. Found together with *Protetragonites* cf. *tripartitus* Raspail sp. and with *Phylloceras* cf. *Kunthi* Neumayr.

Conclusions.

The fauna described in the present paper consists, then, of the following seven Ammonites :—

Phylloceras aff. *Kudernatschi* Hauer.
,, sp. ind.
,, cf. *Kunthi* Neumayr.
,, cf. *disputabile* Zittel.
Sowerbyceras sp. aff. *tortisulcato* d'Orbigny sp.
Protetragonites cf. *tripartitus* Raspail sp.
Hecticoceras sp. juv.

It is a matter for regret that more definite identifications could not be given, but not one of the specimens represents an adult shell, and three of them are fragmentary. It is one of the latter (*Protetragonites* cf. *tripartitus*) that has been mainly relied on in determining the fauna as probably of Bathonian age; but this species already occurs in the *Parkinsoni* beds of the uppermost

[1] As represented by e.g. "*Oppelia*" *retrocostata* Grossouvre ("Études sur l'Étage Bathonien": Bull. Soc. Géol. France, ser. III, vol. xvi, 1888, p. 374, pl. iii, figs. 8, 9), and the Cornbrash species "*Harpoceras*" (*Ludwigia*) *subpunctatum* (Schlippe, "Fauna Bath. Oberrhein. Tiefl.": Abh. Geol. Spec. K. Els.-Lothr. vol. iv, 1888, No. 4, p. 196, pl. v, fig. 3). Haug (loc. cit., 1898, p. 82) considers them identical.

[2] *Amm. Schwäb. Jura*, 1887, pl. lxxxii, e.g. figs. 23 and 32.

[3] Loc. cit., 1873, e.g. pl. xiii.

[4] Loc. cit., 1910, e.g., pl. xviii (iii).

[5] Loc. cit., 1898, e.g. *H. Bonarellii*, de Loriol, pl. iii, figs. 19–21, and 1900, pl. iii, p. 14.

[6] Loc. cit., e.g. "*Harpoceras*" *Guthei*, Noetling, p. 20, pl. ii, figs. 6–8*a*.

[7] Loc. cit., 1852, pl. ii, figs. 9–13.

[8] Loc. cit., 1905, text-fig. 9 on p. 19

Bajocian. On the other hand, it is probable that its record from the *macrocephalus* or even later beds (by several authors) was based on the occurrence of similar forms, which are, as yet, undescribed.

Phylloceras aff. *Kudernatschi* and *Ph.* cf. *disputabile* confirm the Bathonian age, though the latter species has been called "indifferent",[1] and like *Phylloceras mediterraneum* Neumayr, probably includes a variety of more or less closely related forms of its group. Both *Ph. Kudernatschi* and *Ph. disputabile* have been recorded from younger beds, but also from the Bajocian. *Phylloceras Kunthi* has been found in the lower Bathonian, but is a species belonging to the zone of *Macrocephalites macrocephalus*. In India and the Caucasus ammonites, even from the *athleta* beds, have been referred to this species.

The genera *Sowerbyceras* and *Hecticoceras* already occur in the Bathonian, but are typically Callovian and range into higher beds. Arranged according to their localities, *Ph.* cf. *disputabile* and *Sowerbyceras* sp. aff. *tortisulcato* have been found together in the "grey, otherwise unfossiliferous limestone", and *Phylloceras* aff. *Kunthi*, *Protetragonites* cf. *tripartitum*, and *Hecticoceras* sp. juv. were also collected in one bed at the Pipe-line Crossing, Mwachi River. *Ph.* cf. *Kudernatschi* is recorded from a different locality, and *Phylloceras* sp. ind. also was found by itself, west of the Mwachi River. The specimens, therefore, that might suggest a post-Bathonian age, namely *Sowerbyceras* and *Hecticoceras*, occur in each of the two former localities associated with ammonites referred to Bathonian forms, and a Bathonian age thus seems most appropriate to the fauna.

As regards distribution (apart from the European occurrences mentioned under the specific descriptions, and the doubtful record of *Phylloceras* cf. *Kunthi* from India), *Phylloceras disputabile* has been found in India and East Africa, but the ammonites referred to this species probably are not specifically identical with the specimen here recorded. None of the other *Phylloceras* and *Lytoceras* described from the Jurassic of Kutch belong to the types represented in Professor Gregory's collection. From Madagascar also (the "Callovian" beds of which Dacqué considers to be the equivalent of his *macrocephalus* zone of Pendambili) only *Phylloceras mediterraneum*,[2] or a local variant, has been recorded. The latter, together with *Phylloceras Fedden*i Waagen and *Macrocephalites* also occurs in the Iron Oolite of Tanga in East Africa, but the fauna described in the present paper differs from all these in having the group of *Phylloceras heterophyllum* represented, and probably by no less than three different forms.

The lower Bathonian, with a more or less neritic facies, is well developed in the whole of East Africa, but apparently only

[1] Till, op. cit., 1910, i, p. 185.

[2] Also recorded by Suess (*Das Antlitz der Erde*) from Zanzibar.

indeterminable Cephalopod remains so far have been recorded from its rocks. It is interesting to note that six out of seven specimens described in the present paper belong to the long-lived and stable genera *Phylloceras* and *Lytoceras*, giving the fauna a typically Mediterranean aspect. The influx of this Mediterranean fauna must have occurred along the geosynclinal extension of the Tethys, which has been called the "Channel of Mozambique". This geosynclinal, before the Bathonian transgression, apparently had not attained the edge of the present African continent. A *Sonninia* and a *Parkinsonia*, but no *Phylloceras* or *Lytoceras* have been found in the Bajocian of Madagascar, but no pre-Bathonian ammonites occur on the African continent west of this geosynclinal.

Hecticoceras is found in North-West Europe and in the boreal Callovian as well as in Alpine-Mediterranean deposits. On the other hand, *Phylloceras* and *Lytoceras* have been found in Alaska, though there also they are claimed to be confined to a geosynclinal extension of the Mid-Pacific (which latter enabled the exchange of the Spiti and Andine faunas). Professor Haug's conception of *Phylloceras* and *Lytoceras* as stenothermal genera, frequent only in the deepest parts of the geosynclinal areas, does not explain all the facts of their distribution. In a previous paper the writer favoured the view that like other thin-shelled organisms, but unlike many other Ammonites and Nautiloids, *Phylloceras* and *Lytoceras* may have been pelagic swimmers, and thus in their distribution show a certain dependence on the currents of the Jurassic seas.

EXPLANATION OF PLATE V.

Fig. 1.—*Phylloceras* aff. *Kudernatschi* (Hauer). Mombasa Pipe-line, at mile $\frac{12}{5}$. (× about 1·1.) 1*a*, lateral aspect; 1*b*, sectional outline; 1*c*, suture-line (× about 3).

Fig. 2.—*Phylloceras* sp. ind. West of Mwachi River, about $\frac{17}{0}$. Nat. size. 2*a*, lateral view; 2*b*, outline-section; 2*c*, portion of suture-line (× about 3).

Fig. 3.—*Phylloceras* cf. *Kunihi* Neumayr. Mwachi River, Pipe-line Crossing. Nat. size. 3*a*, lateral aspect; 3*b*, peripheral view; 3*c*, suture-line (× about 5).

Fig. 4.—*Phylloceras* cf. *disputabile* Zittel. Mombasa Pipe-line, mile $\frac{11}{11}$. 4*a*, lateral aspect (× about 1·1); 4*b*, opposite side, showing constrictions, with restored outline of complete shell, nat. size; 4*c*, outline-section of whorl, magnified × 2; 4*d*, suture-line (portion) × about 6.

Fig. 5.—*Sowerbyceras*, aff. *tortisulcato* d'Orbigny sp. Same locality as last. 5*a*, lateral aspect (× about 1·1); 5*b*, outline-section, magnified × 2. 5*c*, suture-line, composite and not drawn from one septal edge.

Fig. 6.—*Protetragonites* cf. *tripartitus* (Raspail). Mwachi River, Pipe-line Crossing, about $\frac{30}{0}$. 6*a*, lateral aspect, magnified × 2; 6*b*, section (× 2); 6*c*, suture-line, external and internal (× about 7·5).

Fig. 7.—*Hecticoceras* sp. juv. Same locality as last. 7*a*, lateral aspect (× 2); 7*b*, peripheral view (× 2); 7*c*, suture-line (× about 9).

On the Investigation of the Mechanical Constitution of Loose Arenaceous Sediments by the method of Elutriation, with special reference to the Thanet Beds of the Southern Side of the London Basin.

By Herbert Arthur Baker, M.Sc., F.G.S.

(*Continued from p. 332.*)

Graphical Expression of Mechanical Analyses.

In giving graphical expression to the data obtained by mechanical analyses of sediments, the use of curves was found to be very satisfactory. After some consideration the method finally adopted was to mark off along a horizontal abscissa a scale of percentage-weights, from 0 to 100, and upwards, along a vertical ordinate, a scale of grade-size limits from 0 to ·2 mm. and beyond. In cases where the range of the diameters of the grains in a sample is very great it would be necessary to employ a method of reducing the representative lengths, and this has sometimes been done by marking off lengths proportional to the logarithms of the diameters; but in the case of the arenaceous sediments dealt with by the writer, the necessity for this did not arise, and in the curves illustrating this paper, the ordinate lengths shown are directly proportional to the diameters represented. The length along an abscissa, intercepted between the first ordinate and the curve, represents the *total* percentage weight of the sample which, up to the limit of size specified, has been washed off, and the remaining length signifies the percentage-weight yet remaining to be dealt with. A tendency towards verticality on the part of the curve denotes relative absence or paucity of material of the sizes specified, and, correspondingly, a tendency towards horizontality signifies a preponderance of material of the size specified. Hence, a fine-grained sediment will give a curve occupying the lower part of the diagram, and with increasing coarseness of sediment the curve climbs successively higher and higher. (See Figs. 2, 3, and 6.)

Treatment of Data yielded by Mechanical Analyses.

(1) *Failure of the "Purdy Fineness Factor".*

A method whereby the mechanical constitution of a sediment can be expressed by means of a representative number has been much sought after, but up to the present no really satisfactory result has been achieved. Such a number, could it be obtained, would undoubtedly be of great utility. It could be plotted upon maps, and ideas connecting the mechanical constitution of a sediment with its geographical distribution could be gained. The need for such a number in connexion with the economic aspect of the mechanical composition of sands and clays is much felt. In America an attempt has been made to obtain a "fineness factor" which shall be proportional to the total surface-area of the sample.

The assumption is made that the surface-areas of two powders, derived from a unit volume, are in inverse ratio to the average diameter of their grains, and the reciprocal of the average diameter is taken as the factor. The assumption is now known to be erroneous, but as the factor affords a convenient approximation it is often used. This factor was proposed by Jackson, and amended by Purdy, and goes under the name of the "Purdy fineness factor". It was first propounded to meet the requirements of the ceramic industry, but it has been admitted that since the difference between the true surface-factor and that calculated from the average diameter increases as the diameter decreases, more confidence may be placed in the Purdy factor as calculated for sediments coarser than the fine material used in the ceramic industry. The method of obtaining the Purdy fineness factor will be clear from the following:—

Suppose the sample to have been separated by elutriation into four grades, thus:—

Grade.	Diameters ranging from	Average Diameter.	Surface Factor.	Percentage-weight present.
1	a to b mm.	$\frac{a+b}{2}$ mm.	$\frac{2}{a+b}$	A
2	b to c ,,	$\frac{b+c}{2}$,,	$\frac{2}{b+c}$	B
3	c to d ,,	$\frac{c+d}{2}$,,	$\frac{2}{c+d}$	C
4	d to e ,,	$\frac{d+e}{2}$,,	$\frac{2}{d+e}$	D

Then the Purdy fineness factor = total surface factor =

$$\left(\frac{2}{a+b}\times\frac{A}{100}\right)+\left(\frac{2}{b+c}\times\frac{B}{100}\right)+\left(\frac{2}{c+d}\times\frac{C}{100}\right)+\left(\frac{2}{d+e}\times\frac{D}{100}\right)$$

The total surface-factor is obtained by multiplying the surface-factor of each grade by the percentage-weight of that grade, and finding the sum of the products thus obtained.

Before proceeding to test the utility of the Purdy fineness factor in relation to arenaceous sediments, it is legitimate first to make the criticism that the true average diameter of the grains in any separated grade is likely to be seriously different from the half-sum of the limiting sizes.

Bearing in mind that the Purdy fineness factor should show larger numbers for finer sediments, the above formula was applied to the results of a large number of mechanical analyses carried out on arenaceous sediments by the writer. The result was to show the complete failure of this factor to serve any useful purpose as a means of comparing arenaceous sediments from the point of view of fineness

or coarseness of grain. The following selected pair of sediments will suffice to illustrate this point :—

	Clay.	Silt.		Sand.			
	mm. <·01	mm. >·01 <·05	mm. >·05 <·1	mm. >·1 <·125	mm. >·125 <·15	mm. >·15 <·2	mm. >·2
Sample *A*.	3·72	1·58	8·48	29·86	50·26	4·22	1·88
Sample *B*.	0·78	11·54	52·68	29·62	4·90	0·48	—

Both samples are of the Thanet Sand from Messrs. Tuff & Hoar's Pit, East Wickham, but whereas sample *A* is from the extreme top of the deposit, sample *B* is from about the middle of the deposit. The mechanical analysis reveals at once that sample *A* is a distinctly coarser sediment than sample *B*. In the case of sample *A*, over 50 per cent of the material is sand between the limits of ·125 and ·15 mm., whereas in the case of sample *B* over 50 per cent is of the coarse silt grade. When the elutriation curves of the two sediments are plotted this distinction is very clearly shown. (See Fig. 2.) The calculation of the Purdy fineness factor should therefore produce the larger number in the case of sample *B*. But this is not the case, viz. :—

Sample *A*. Purdy factor =

$$\left(\frac{1}{\cdot005}\times\cdot0372\right)+\left(\frac{1}{\cdot03}\times\cdot0158\right)+\left(\frac{1}{\cdot075}\times\cdot0848\right)+\left(\frac{1}{\cdot1125}\times\cdot2986\right)$$

$$=\frac{\cdot0372}{\cdot005}+\frac{\cdot0158}{\cdot03}+\frac{\cdot0848}{\cdot075}+\frac{\cdot2986}{\cdot1125}$$

$$=7\cdot44+\cdot53+1\cdot13+2\cdot65$$

$$+\left(\frac{1}{\cdot1375}\times\cdot5026\right)+\left(\frac{1}{\cdot175}\times\cdot0422\right)$$

$$+\frac{\cdot5026}{\cdot1375}+\frac{\cdot0422}{\cdot175}$$

$$+3\cdot65+\cdot24$$

$$=15\cdot64.$$

In the case of sample *B* the figures are :—

Purdy factor =

$$\frac{\cdot0078}{\cdot005}+\frac{\cdot1154}{\cdot03}+\frac{\cdot5268}{\cdot075}+\frac{\cdot2962}{\cdot1125}+\frac{\cdot0490}{\cdot1375}+\frac{\cdot0048}{\cdot175}$$

$$=1\cdot56+3\cdot85+7\cdot02+2\cdot63+\cdot35+\cdot02$$

$$=15\cdot43$$

Hence we see that the very insignificant difference obtained is on the wrong side.

It becomes necessary, therefore, to seek another basis of

comparison for the fineness or coarseness of grain of arenaceous sediments.

From the mathematical point of view the question presents great difficulties. It does not appear to be possible to apply any simple mathematical process to the data afforded by elutriation, which does not deprive them of their uniqueness. Moreover, the applica-

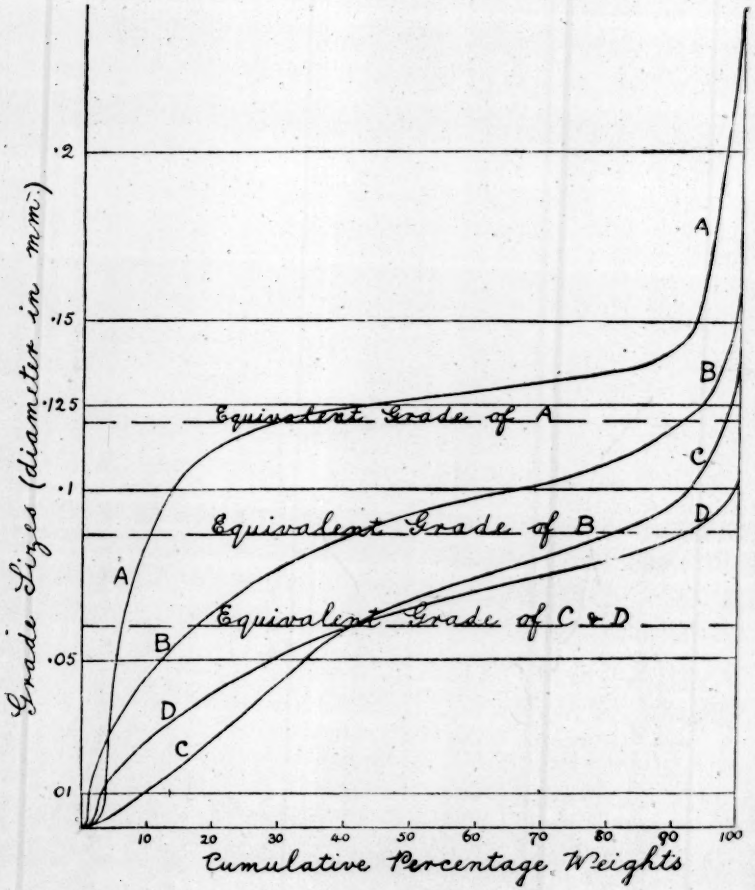

FIG. 2.—Elutriation curves of sediments (reduced) to show meaning of "Equivalent Grade".

tion of the ordinary processes of mathematics to the elutriation-curve of a sediment would only give some result or results based upon a series of mathematical curves agreeing more or less approximately with portions of the actual curve. The latter being available, the present writer is of opinion that it is better to obtain some result or results from actual treatment of the graph itself.

In the search for a characteristic number to represent the mechanical constitution of a sediment, the actual average diameter of the grains in a sample, besides being exceedingly difficult, if not impossible to obtain, is useless, since it gives a result quite out of keeping with the sizes of the grains in the bulk of the sample. This arises from the fact that the clay grade in the sample, however insignificant its percentage-weight may be, contains such an enormous amount of tiny particles that the average diameter is reduced to a figure of an order quite different from that sought. Consequently a method is required which affords a result influenced by the percentage-weights of the various grades present.

(2) *The "Equivalent Grade" of a Sediment.*

The plotting of the elutriation-curve of a sediment from the data yielded by the mechanical analysis of it, affords a means of obtaining graphically, the value of the definite integral of diameter of particles with respect to percentage-weight. The value of this integral is represented by the area under the curve enclosed between the first and last ordinates and the first abscissa or base-line of the diagram. It may readily be determined, with considerable accuracy, by the use of the planimeter. The result is small or large, according as the sediment under consideration is fine or coarse, since the coarser the sediment the higher its curve climbs and the greater the area enclosed beneath it. If we suppose the case of an ideal sediment in which the grading is perfect (i.e. the sediment consists entirely of grains of some one specified diameter), the elutriation-curve would be a horizontal straight line (an abscissa), parallel to the first abscissa and passing through the point on the first ordinate representing the specified diameter. Let us suppose, for argument, that all the grains in this ideal sediment are of diameter 0·2 mm. Then the area under the curve is a rectangle whose area is a product of the length representing 0·2 mm. and that representing 100 per cent weight. The figure sought as the representative average of the diameters of the particles (taking into account percentage-weights of grades) is obtained by dividing the area under the curve by the length of the base-line representing 100 per cent weight, and interpreting the length so obtained in terms of the scale of lengths employed to represent diameters. Now, perfectly graded sediments of this kind do not appear to occur in nature, but there is no reason why we should not extend the argument, by analogy, to apply to actual sediments. Consider an imperfectly graded natural sediment. It gives a certain known value for the integral of diameter of particles with respect to percentage-weight. Suppose it were possible to substitute for this sediment a perfectly graded material giving an equivalent value for the area under the curve. What would be the diameter of the particles in this ideal sediment? The answer is supplied by finding the mean ordinate of the area under the curve,

which is done by finding the area under the curve by means of the planimeter and dividing the result by the length representing 100 per cent weight. The length so obtained is then interpreted in terms of the scale of lengths employed to represent diameters. The value of this mean ordinate may then very well be taken as the representative diameter, for comparative purposes, of the particles in the sediment. The figure obtained may be termed the "Equivalent Grade" for the particular sediment.

Fine sediments will give a low figure for the "Equivalent Grade" and the figure will increase with increasing coarseness of sediment.

On applying this method to the two sediments considered above when referring to the Purdy factor, we find that sample *A* (the coarser sediment) gives an Equivalent Grade of ·120 mm., whereas the finer sample *B* gives ·087 mm. As the result of applying the method to the data obtained by carrying out a very large number of mechanical analyses of arenaceous sediments, the writer now concludes that we have, in this "Equivalent Grade", a valuable means of comparing sediments from the point of view of their coarseness or fineness of grain, and one superior to any method at present in vogue.

(3) *The "Grading Factor" of a Sediment.*

It cannot be said, however, that the Equivalent Grade supplies a figure which is unique for each and every sediment. The elutriation curve of a sediment is unique—each and every sediment gives its own particular curve—and only two mechanically identical sediments would yield identical curves. It is possible, however, for two different curves to yield the same Equivalent Grade figure. Hence it is necessary for a further factor to be obtained, based upon the respective proportionalities of the grades present in the sediment, so that this second figure, taken in conjunction with the Equivalent Grade, affords a pair of numbers which together give complete uniqueness to any sediment. The writer has devised a means whereby a second figure—a "Grading Factor"—can be obtained, so that if two sediments give the same Equivalent Grade they differ in their Grading Factor, and vice versa. Incidentally, the Equivalent Grade and the Grading Factor of a sediment are figures which should prove of the utmost utility in connexion with the economic aspect of the question of the mechanical constitution of sediments, and, further, there is every reason to suppose that as our knowledge of the conditions governing the transport, sorting, and deposition of sediments progresses, they will, in addition, prove of considerable value to the geologist.

The Grading Factor of a sediment is found as follows: Curve *C* in Fig. 2 represents the elutriation-curve of a sediment (Lower Thanet Beds, Charlton Pit), which gave the following mechanical analysis:—

Clay.	Silt.		Sand.	
<·01 mm.	>·01 mm. <·05 mm.	>·05 mm. <·1 mm.	>·1 mm. <·125 mm.	>·125 mm.
9·52	24·17	58·98	6·01	1·32

The Equivalent Grade of this sediment, determined from the curve, is ·059 mm., and its equivalent, perfectly graded ideal sediment is represented by the horizontal abscissa inserted on the graph in the appropriate place.

Now, the area enclosed between the first ordinate, the Equivalent Grade line, and the curve, represents the measure of the *variation* of the sediment (having regard to diameters and percentage-weights) *below* the grade of the ideal, perfectly graded equivalent sediment, and the corresponding equal area enclosed between the last ordinate, the Equivalent Grade line, and the curve, similarly represents the measure of the variation of the sediment *above* the grade of its ideal, perfectly graded equivalent. Hence, the sum of these two areas gives the measure of the *total* variation of the sediment from the hypothetical perfectly graded equivalent. If we now subtract this variation-area from the total area under the curve we get a remainder which expresses the measure of the tendency of the sediment towards constancy of grading or restriction of the diameters of the constituent grains to one specified size, namely that of the Equivalent Grade. In the case of a hypothetical perfectly graded sediment, that is, one in which there is perfect constancy of grading, or complete restriction of the grain diameters to one particular dimension, there is no variation-area, consequently the area which expresses the measure of its tendency towards grading perfection is the area under the curve.

Hence, if we consider the ratio—

$$\frac{\text{Area expressing measure of tendency towards grading perfection}}{\text{Total area under curve}}$$

we see that it assumes the value unity when the grading is perfect. The Grading Factors of naturally occurring sediments will approach nearer and nearer to the value unity as their degree of grading approaches nearer and nearer to perfection. Hence, the Grading Factor of a sediment is given by :—

$$\frac{\text{Total area under curve} - \text{Total variation area}}{\text{Total area under curve}}$$

Determining, with the aid of the planimeter, the Grading Factor of the sediment under consideration, we obtain the value ·581.

Shown on the same diagram (curve *D*) is the elutriation-curve of another sediment (Lower Thanet Beds, Tuff & Hoar's Pit, East Wickham), which gave the following mechanical analysis :—

Clay.	Silt.		Sand.
<·01 mm.	>·01 mm. <·05 mm.	>·05 mm. <·1 mm.	>·1 mm.
2·90	26·20	70·90	—

The Equivalent Grade of this sediment is identical with that of the first, viz. ·059 mm., but the two curves are not identical. It can be seen at a glance that the first sediment shows greater variation than the second, and hence the latter yields a higher Grading Factor, the value in this case coming out at ·693. We see, then, that the Equivalent Grade of a sediment together with its Grading Factor afford a pair of values unique for any sediment.

It should be remarked that in selecting sediments to serve as illustrations of the utility of these two factors, the writer has deliberately chosen examples in which the differences in mechanical constitution are by no means great. In general, arenaceous sediments show very much greater differences in mechanical composition than are to be observed in the examples selected. If, then, comparatively insignificant differences can be indicated by the methods of treatment here outlined, how much more apparent become the greater differences very generally found.

When the data yielded by mechanical analyses of sediments have accumulated sufficiently, it should be a simple matter to draw up a scheme of classification, according to mechanical constitution, for the loose detrital sediments, based upon determined values of Equivalent Grades and Grading Factors. The determination of the values of these factors in the case of those sediments which are used in the industries can hardly fail to be of great utility. The importance of mechanical constitution in the case of glass sands and in the case of the refractory sands used for furnace and foundry purposes has already been clearly demonstrated by Professor Boswell. But from the purely geological point of view there is every reason to believe that from the detailed study of the mechanical constitution of the loose detrital sediments of the geological column, much light will be thrown upon many obscure questions, especially in reference to conditions of deposition of sediments. When palæontological evidence fails, the stratigrapher is thrown back upon the lithology of the deposits, and in the case of a loose, arenaceous sediment the lithological evidence is very strongly and helpfully augmented if the elutriation-curve be available.

(To be continued.)

REVIEWS.

Echinoid or Crinoid ?

Ueber einige palaeozoische Seeigelstacheln (*Timorocidaris* gen. nov. und *Bolboporites* Pander). By Johannes Wanner. Versl. Natuurk. Afdeel. Akad. Wetensch. Amsterdam, xxviii, pp. 797–813, pl. 1920.

PROFESSOR WANNER has found in the Permian of Timor some echinoderm remains which he believes to be radioles of an echinoid, and therefore names *Timorocidaris*. In shape one of these objects is like a mushroom, with rounded top and short stalk. The alleged upper outer face is normally pustulate, but sometimes smooth. The circular outline is sometimes modified by truncations, as though these supposed radioles had been crushed close together on the test, as are the radioles of *Colobocentrotus*. The large majority (2,150 out of 2,422) of these bodies have the end of the stalk bevelled off by three facets, which meet round a small central hollow. "The remarkable feature is that these three surfaces are fashioned as articular facets with a pronounced crinoid character." Each facet shows the fulcral ridge, separating an outer crescentic ligament-face from the two inner muscle-plates, which are divided by a median groove or notch. At the middle of the ligament-face, adjoining the fulcral ridge and opposite the notch, is a depression, which may indicate a more pronounced ligament-scar (as Dr. Wanner interprets it) or a canal for a nerve. Some of the remaining specimens have merely a hollow at the end of the stalk, and Dr. Wanner believes that this hollow represents one of the facets. He claims to have material proving a passage from one type of structure to the other, but his figures are not convincing. Some of the specimens have an ornament resembling that of *Cidaris scrobiculata* and one or two other radioles from the Alpine Trias.

It is possible that there are some true echinoid radioles in this material, but I am at a loss to understand how the majority with the three articular facets can be interpreted thus. Setting aside the fact that no such structure has ever been seen in the Echinoidea, is it not obvious that such facets could not have been used for the attachment of one rigid body to a single rigid surface of whatever shape ? Each of these facets must have been attached to a separate, movable, skeletal element of similar section, i.e. with a rounded outer back and grooved inner surface. That which was fixed as the stalk, that which was movable, was the group of structures attached to the facets. Those structures must have diverged from one another at the outset.

Dr. Wanner makes a number of hypotheses, each of which he tests conscientiously and finds unworkable ; he also exerts himself

to smooth away certain other objections to regarding these objects as radioles; *inter alia* the total absence from his collections of any coronal plates to bear them. It never occurs to him to make the hypothesis that these objects are crinoids after all. Let us see how that works out. Each, we may suppose, has normally three radials, laterally fused into a short stalk, and springing from a solid rounded mass into the composition of which the basals (and infrabasals, if any) presumably enter. Each radial facet supported, on this hypothesis, the first brachial of an arm. As to the nature of those arms we have no evidence other than that afforded by the facet, from which we gather that they were independently movable and moderately massive. They must have included the viscera, since there is not sufficient space between the radials, and therefore were probably joined laterally by a finely plated membrane.

On this hypothesis the hemisphere from which the radial stalk springs was a sort of anchor resting on the sea-floor, perhaps sometimes embedded in sand or sometimes inserted in a crevice which checked its free growth. Some of the specimens may have been dragged along the bottom and so lost their pustules. Others may have been partly weathered and have had their facets eaten away. Individuals fixed in awkward positions may have developed one or two facets at the expense of the others. All such aberrant cases do not amount to 12 per cent. The crinoid hypothesis, then, seems open to fewer objections than the echinoid. Just as Dr. Wanner's *Timorechinus* proved to be a crinoid allied to the Poteriocrinidæ, so his *Timorocidaris* will probably turn out to be a crinoid with stem reduced to a massive anchor, as in *Agassizocrinus*, and with arms reduced to three, as in *Tribrachiocrinus*. It may be genetically connected with one or other of those late Carboniferous genera, but that is not a necessary conclusion.

Professor Wanner argues from his supposed radioles with their abnormal facets to *Bolboporites*, which likewise he interprets as an echinoid radiole with a peculiar facet. If, however, *Timorocidaris* be a crinoid, this analogy loses its force. In no other respects does Dr. Wanner throw fresh light on *Bolboporites*. Had he taken the trouble to make thin sections through his specimens and to study their stereom with the microscope, he might have substituted some useful fact for a deal of ingenious but, I fear, useless fancy.

F. A. Bather.

The Palæozoic Tillites of Northern Norway. Bidrag til Finmarkens Geologi, av Olaf Holtedahl. Norges Geologiske Undersökelse, Nr. 84. Kristiania, 1918.

In 1890 Dr. H. Reusch announced his discovery in the Varangerfjord district, E. Finmarken, of rocks of glacial origin "belonging to a much older period than the Ice Age". He referred them to the Palæozoic, and, relying upon the petrographical similarity of the beds associated with the tillites to the Sparagmite

Formation of Norway, suggested that they were of Torridonian or Lower Cambrian age. A Quaternary age was subsequently advocated by O. E. Schiötz, but Sir A. Strahan supported Dr. Reusch's interpretation. Whilst the deposits certainly belong to the Palæozoic, there was very little evidence for regarding them as Cambrian, yet this was widely accepted, and the Varangerfjord beds are commonly correlated with similar deposits of Cambrian age in China and Australia, and cited to support the hypothesis of a Cambrian ice age. As a result of detailed work in the northernmost part of Norway, Dr. O. Holtedahl places a new interpretation upon the age and significance of the tillites.

The succession in Finmarken is made out as follows :—

Sandstone Series { *Upper* with tillites. *Lower* with dolomites, and, in the west, volcanic rocks.

Lower Cambrian shales with *Platysolenites antiquissimus* and *Obolus* sp.

Pre-Cambrian.

The pre-Cambrian gneisses and schists occupy the southern part of the area—the later sedimentaries occurring to the north, and being themselves covered in the north-west by an overthrust metamorphic series dating from the Caledonian movements. The discovery in Spitsbergen of Downtonian sediments lying unconformably upon the eroded remnants of the Caledonian Range prove that in this region this great deformation was completed before Upper Silurian times, and therefore the tillites can be referred to some period between the Lower Cambrian and Upper Silurian. The Sandstone Series has not yet yielded any fossils, and its more definite age has to be inferred from a comparison with the rocks of neighbouring regions.

The Lower Sandstone Series follows conformably upon the Lower Cambrian and is notable for its thick beds of magnesian limestone, commonly entirely composed of dolomite—intraformational conglomerates occur. These dolomites are often oolitic, and contain chert nodules and abundant stromatolitic forms, and they are correlated with the Durness Limestone and similar North American beds of Upper Cambrian and Lower Ordovician age. The land barrier separating the northern part of Great Britain with its North American fauna from the southern, seems to have extended north-east to South Finmarken, where it separated the northern sea of the Arctic Province with its characteristic dolomites from the southern in which the Kristiania beds of normal South British type were deposited. The volcanic rocks of West Finmarken are paralleled with the Lower Ordovician lavas of Central Norway and South Scotland.

The Lower Series was folded and faulted before the deposition of the Upper, which lies unconformably upon both the pre-Cambrian and the Lower Sandstones. The Varangerfjord fault runs east to

west, with its downthrow side to the north, and these movements are correlated with the Middle Ordovician disturbances of Scotland and North America. The Upper Series derived its material from the highland south of the fault, which was a pre-Cambrian area, in part belonging to the land barrier, with remnants of the lower dolomite-bearing series.

The tillites occur at two horizons. The lower is a local deposit resting upon a grooved pavement, and containing ice-scratched boulders of gneiss, granite, and sandstone. Associated conglomerates contain pebbles of chert, and dolomite with oolitic and stromatolitic structures. The upper tillite contains ice-scratched boulders, but is of a different character; it is of very even thickness, extends over a wide area, and passes downwards into the even-grained ungrooved sandstones beneath, thus indicating a glacial deposit laid down under water from floating ice. The lower tillite, on the other hand, is of a continental type.

Dr. Holtedahl refers the tillites to some period between the Lower Ordovician and Upper Silurian, and lays stress upon the fact that they do not necessarily indicate a climate as cold as that of northern Norway at the present day. It is to be hoped that fossils will soon be found in these beds, and their exact age established beyond doubt. Their non-discovery up to the present is not incompatible with the age postulated, for considerable thicknesses of the Durness Limestone are barren, and limestones of undoubted Cambro-Ordovician age in North America of the same petrographical character have failed to yield fossils. Dr. Holtedahl's researches indicate that the tillites were formed before the Caledonian deformation attained its maximum, which was in Lower and Middle Silurian times, and that no general climatic change is to be inferred from them.

L. Hawkes.

The Arbouin Copper Mines at Cardross. By L. C. Ball. Queensland Geological Survey, Publication No. 261. pp. 69. Brisbane, 1918.

THE Arbouin Copper-mines are situated in North Queensland, about 20 miles west of Mungana, the terminus of the Chillagoe Railway. Geologically the Cardross district is composed entirely of pre-Silurian schists and gneisses, and only to the east, about Mungana, are these overlaid by Silurian shales and limestones. The schists and gneisses have been invaded by an old series of basic dykes, now in the condition either of amphibolites or diorites, and later, probably at the time of the intrusion of the Permian granites by pegmatites and elvan dykes, accompanied by metalliferous lodes.

There are several belts of mineralization, and the trend of these and of the individual lodes is about north-east and south-west. The elvans, though having a trend generally at right angles to the lode direction, are evidently closely connected with the ore bodies.

since in proximity to a dyke the lode is always richer, while in the absence of dykes the lodes are often barren. This relationship, coupled with the fact that the dykes often carry sulphides in workable amount, leads the author to the conclusion that the metalliferous solutions were introduced along the dyke fissures. The unoxidized sulphide ore consists for the most part of copper pyrites, mispickel and iron pyrites either branching and intergrown or finely granular, accompanied sometimes by tourmaline. An interesting variety, found on the Chieftain mine, contains magnetite, both in the form of round pellets and of threads intergrown with the copper pyrites.

The lodes show a very well-marked division into the three zones of oxidation, secondary enrichment, and sulphide ore. Since there is no carbonate in the country rock, the salt produced was the soluble sulphate, which was promptly carried down to the lower levels, leaving the oxidized zone for the most part free from copper compounds, except for the arsenate olivenite. This mineral, on one claim, provided quite a large yield of ore, a fact which constitutes somewhat of a curiosity in copper-mining.

The zone of enrichment includes chiefly the minerals tile ore, covellite, chalcocite, bornite, and copper pyrites; it is of irregular extent, but rarely exceeds a depth of 50 feet below ground water level. In the unoxidized portions of the lodes the richer ores are found in long narrow shoots, which may be several hundreds of feet long, but are only from 2 to 6 feet wide; in addition to the shoots the lodes contain large supplies of low-grade ore, which are now being worked on account of the uncertainty and irregularity of the shoots.

A fair amount of development work has been done on the field, and a smelter has been erected and worked for several short periods. The percentage of copper in the ores after hand-picking may rise as high as twenty, but the more usual level is about seven. The great difficulty, however, in mining at a profit is not the ore but the cost of transport to and from Cairns, the nearest port, which is so high as to make profitable working of the mines a very difficult matter.

W. H. W.

THE KENT COALFIELD: ITS EVOLUTION AND DEVELOPMENT. By A. E. RITCHIE. pp. x + 309, with illustrations, maps, and sections. Iron and Coal Trades Review, 1919. Price 7*s.* 6*d.*

THE world at large, and particularly the busier inhabitants of it, owe a great debt to compilers, and this debt is in no way reduced by the issue of Mr. Ritchie's book on the Kent Coalfield. The book is the result of the sifting of a vast mass of information, geological, statistical, and financial, which must have been, to a very considerable extent, in such inaccessible places as the files of the daily papers and company reports.

The author treats the subject historically, which is certainly the most convenient way of placing before us the story which he tells, but, as geologists, we could have wished that he had, at any rate,

departed for a while from this course and gathered together the information from the various borehole sections which he gives. Of course the correlation of coal-seams is at present quite impossible, yet with the material now in hand it has been found to be possible to obtain at least a general view of the broad outlines of the structure of the coalfield. With this criticism we may pass on to the historical part of the subject-matter. The history of the field, from the early days when Godwin-Austen was trying to convince an unwilling public of the existence of coal in Kent, to the present stage of shaft-sinking and coal-producing, is admirably told, particularly that part of it which is connected with the financial transactions. These, to one unversed in such matters, read more like romance than sober fact, but no less amazing is the incredible persistency with which everyone connected with the coalfield continued to "back the wrong horse" on every possible occasion. Borings were put down on wrong theories, strata highly charged with water were assumed to be quite water-free, shafts were sunk without sufficient pumping-gear, in short almost every wrong assumption which could be made seems to have been made and acted upon; and yet there is now the Kent Coalfield, a going concern and one which would be now much more active were it not for the War and the threat of nationalization which is hanging over the head of so much colliery enterprise.

The book is very readably written, and the author is to be congratulated on having brought out the first connected account of the development of this very interesting area.

W. H. W.

THE SUBMERGED FOREST AT BOMBAY. By T. H. D. LA TOUCHE. Rec. Geol. Surv. India, vol. xlix, 1919, pp. 214–19, with plates 17–19.

ABOUT thirty years ago many tree-stumps, submerged about 20 feet below mean sea-level, were discovered during the excavation of the Prince's Dock, Bombay, and described in the *Records*, vols. xi and xiv. In 1910, during the extension of the Alexandra Dock to the south of the former site, more stumps were discovered and examined by Mr. La Touche. The stumps, 6 or 7 feet high, were rooted in a thin soil on the surface of disintegrated basalt, and embedded in blue clay, which included shells of *Ostrea cucullata* with valves united. The depth below high water-mark of the rock-surface is about 40 feet, which gives a minimum value for the total amount of depression. These two occurrences prove a considerable subsidence of the rocky floor, on the western side of Bombay harbour, apparently within human times, since one of the stumps seen in 1878 was partly burnt. This subsidence is interesting when considered in conjunction with the well-known occurrence of a raised beach in the same neighbourhood.

THE PORTO RICO EARTHQUAKE OF 1918. Report of the Earthquake Investigation Commission. By H. F. REID and S. TABER. Washington. 1919.

THE authors of this valuable memoir are experienced seismologists. Professor Reid wrote the second volume of the great report on the Californian earthquake of 1906, Mr. Taber has published accounts of several minor shocks in the United States. The earthquake here studied occurred without warning on October 11, 1918, shortly after 2 p.m. (Greenwich mean time), lasted two minutes, and was one of the most severe shocks felt on the island since its occupation by Europeans. Considerable damage to property occurred in the north-western corner of the island, and, from the distribution of the damage and from the evidence of the seismic sea-waves, the authors place the epicentre in the north-eastern part of Mona Passage (between Porto Rico and San Domingo). They consider that the earthquakes were caused by sudden fractures of the rocks forming the ocean-bed, and that the fractures probably occurred along an old fault. It is clear that the crust is still subsiding in the district surrounding the epicentre, for during the last half-century there has been a slow depression of the neighbouring coasts of Porto Rico. Soundings near this coast have revealed the existence of an extraordinary submarine valley running in a north-westerly direction and bounded by slopes which are so precipitous (amounting to $3\frac{1}{2}$ kilometres in less than 15 kilometres) that they can only be explained as the result of faulting. A sudden fracture and vertical displacement of the rock along a fault or faults near the head or on one side of this depression would, as the authors remark, account for all the phenomena of the earthquake. The memoir, which is one of the most important of recent contributions to seismology, concludes with a description of the Virgin Islands' earthquakes of 1867-8, and a catalogue of all known earthquakes felt in Porto Rico and the Virgin Islands from 1772 to 1918. C. D.

ON PITCHBLENDE, MONAZITE, AND OTHER MINERALS FROM PICHHLI, GAYA DISTRICT, BIHAR AND ORISSA. By G. H. TIPPER. Rec. Geol. Surv. India, vol. i, 1919, pp. 255–62, with three plates.

A DESCRIPTION is given of an interesting occurrence of rare minerals in a large mass of pegmatite intrusive into garnetiferous mica-schists. The pegmatite consists of quartz, microcline, and greenish mica with pink garnets and apatite. The pitchblende remains as cores in rounded nodules of uranium ochre formed by its oxidation. A few examples were found of cubo-octahedral pseudomorphs of uranium ochre after uraninite. Torbernite and less commonly autunite are found encrusting mica, apatite, and other minerals. Monazite forms isolated crystals and

masses in the felspar, often intergrown with columbite, mica, or apatite. Many of the crystals are unusually large; one crystal fragment weighed 500 grams, and a solid mass of 1·5 kilos was found; an average of three analyses gave 9·95 per cent ThO_2. Columbite builds fan-shaped aggregates in the felspar; the crystals are always singly terminated and often very large; one weighed over 6 kilos.

Special Reports on the Mineral Resources of Great Britain. Vol. XV: Arsenic and Antimony Ores. By H. Dewey, with contributions by Dr. J. S. Flett and G. V. Wilson. Memoirs of the Geological Survey. pp. iv + 59, with 2 figures and 1 plate. 1920. Price 3*s.* net.

THIS, the fifteenth volume of this valuable series, gives a comprehensive review of the British resources of ores of arsenic and antimony. The ores of arsenic have not been found in notable quantity in Britain outside Cornwall and Devon, but there the output is large, mainly as a by-product in the treatment of ores for tin and tungsten. Of late years the total production has averaged about 2,500 tons per annum of crude and refined arsenic, which is mainly used in the preparation of insecticides and to a less extent in glass-making; it is also employed in calico-printing, for hardening lead shot, and in medicine. All the arsenic is derived from mispickel.

An interesting account is given of the mines where arsenic is or has been produced in Cornwall and Devon, including a useful diagram, not, however, quite complete, of the lodes in East Pool Mine.

The production of antimony from the British mines is almost negligible in amount; the Glendinning Mine, in Dumfriesshire, here described by Mr. G. V. Wilson, has yielded a few tons. Dr. Flett gives an account of the antimony-bearing veins of the Knipes Mine, near New Cumnock, in Ayrshire, which carry stibnite in uncertain quantity. In Cornwall the antimony-bearing minerals jamesonite, bournonite, and tetrahedrite occur in small quantity, but these, as well as stibnite, are there mainly mineralogical curiosities.

REPORTS AND PROCEEDINGS.

Mineralogical Society.

June 15.—Dr. A. E. H. Tutton, F.R.S., Past President, in the chair.

F. P. Mennell: "Rare zinc-copper minerals from the Rhodesian Broken Hill Mine, Northern Rhodesia." Copper minerals, including malachite, chessylite, copper-glance, and undetermined phosphates are of rare occurrence in the lead-zinc ore of this locality. Still rarer are the copper-zinc minerals aurichalcite and veszelyite; the latter forms minute, sky-blue, monoclinic crystals ($a:b:c = \cdot971:1:\cdot95$), and differs from the original mineral from Hungary in its colour and in containing little or no arsenic.

Professor R. Ohashi: "Note on the Plumbiferous Barytes from Shibukuro, prefecture of Akita, Japan." This mineral, which is deposited as a white to brownish-yellow crystalline crust in the fissures and near the orifices of hot springs, is similar to the mineral recently called "hokutolite" from Taiwan (= Formosa); it contains 4·69 to 17·78 per cent of PbO, and is radio-active.

W. A. Richardson: "The Fibrous Gypsum of Nottinghamshire." The relation to the nodular types of gypsum of the fibrous veins of the mineral which are associated with every other type of gypsum deposit in the district, and occur at levels where there is no other development of the mineral, was considered. Most of these veins are regarded as having been formed shortly after the nodular deposits. The fibres grew upwards and downwards from a plane in the marl, and were probably deposited by descending solutions, being precipitated at planes of tension in a contracting medium. The veins of fibrous calcium carbonate or "beef" described by Dr. Lang show similar structure and field relations, and doubtless originated under similar conditions.

W. A. Richardson: "A new Model Rotating-stage Petrological Microscope." This instrument is intended as a substitute for the larger pre-War models, which at the present time could only be manufactured at very high prices. It is provided with a mechanical stage, interchangeable with a plane stage and a conventional substage, and provision is made for rapid change from parallel to convergent polarized light. Owing to the reduction in size a rotation of 270 degrees only can be provided for the rotating stage.

W. Barlow: "Models illustrating the Atomic Arrangement in Potassium Chloride, Ammonium Chloride, and Tartaric Acid." In the case of the chlorides the suggested structure reconciles the X-ray phenomena with the crystalline symmetry. The arrangement proposed for tartaric acid agrees with the graphical formula of the chemists, and the molecular groups have the symmetry and relative dimensions of the crystals.

GEOLOGISTS' ASSOCIATION.

June 4, 1920.

"The Theory of Isostasy: its geodetic basis and its geological implications." By A. Morley Davies, D.Sc., F.G.S.

Plumb-line and pendulum anomalies. Historical summary: Bouguer, Petit, Pratt, Airy.

Static ideas of "compensation" become dynamic in hands of geologists: Osmond Fisher, Dutton.

Later geodetic developments: Hayford, Bowie, Burrard. Strength of the earth's crust: Barrell, Oldham.

Mistaken applications of the principle of isostasy by geologists. Great thickness of the shallow-water deposits, so far from being a consequence of isostasy, indicate its imperfection. Analysis of the case of the Weald.

July 2, 1920.

"On the Beds at the Base of the Ypresian (London Clay) in the Anglo-Franco-Belgian Basin." By L. Dudley Stamp, M.Sc., A.K.C., F.G.S.

Brief description of typical sections, showing the relation between the London Clay and the Lower London Tertiaries, throughout the London "Basin". The distinctive fauna of the Blackheath Beds contrasted with that of the underlying Woolwich Beds, and compared with that of the London Clay Basement Bed. Reconstruction of geographical conditions during Lower Eocene times. Evidence of the gradual but intermittent uplift of the Weald and its effect on the deposition of the Eocene beds.

The succession in Belgium. Description of new and typical sections. Oldhaven Beds. Close relation to deposits of London Area. The succession in the Paris "Basin". Remarkable similarity of geographical conditions compared with London. The Sinceny Beds—the homotaxial equivalents of the Blackheath (Oldhaven) Beds—have a similar fauna and were found under similar conditions.

The succession in the Hampshire "Basin". Connexion with Paris "Basin".

Faunal notes on the Blackheath–Sinceny Beds.

Summary: The London, Belgian, Paris, and Hampshire Eocene regions form parts of one great basin which has a common history. Essential to consider all parts of this basin in any discussion on Eocene rocks of one region. Blackheath–Sinceny Beds the result of the marine invasion of Ypresian times under special geographical conditions. Retained as a separate division but part of the Ypresian cycle. Marked change from conditions of formation of the underlying Landenian (Thanet Sands, Woolwich and Reading Beds).

"On the Stratigraphical and Geographical Distribution of the Sponges of the Inferior Oolite of the West of England." By L. Richardson, F.R.S.E., F.G.S.

CORRESPONDENCE.

GLACIAL EROSION OF SNOWDON.

SIR,—Professor Gregory's article on "The Pre-Glacial Valleys of Arran and Snowdon" in your April number does not give, as far as Snowdon is concerned, sufficient evidence for the form that he assumes for the Preglacial valleys. The question is, as he says, "merely how far the glaciers enlarged and deepened these pre-existing valleys." He quotes Ramsay as to the local glaciers "escaping from the high bounding-walls of the upper parts of their valleys", and infers from this that Ramsay thought "the valleys [that is the valleys in their existing form] were pre-Glacial". That was very likely Ramsay's opinion, but as he thought that the Snowdon glaciers merely scoured the pre-existing cwms and valleys, and as he gave practically no consideration to their possible excavation by glacial erosion, his views on the mooted question count for little.

Professor Gregory goes on to say: "The uplift of Snowdonia led to the erosion of canyons along the floors of the old valleys, the width of which indicates that they had been worn down to base-level and their walls cut backward before the Glacial period." It is here implied that the width of the Preglacial "canyons" is known; but as a matter of fact, their width as well as their depth is in question. The question cannot be satisfactorily solved simply by assuming, as Professor Gregory seems to do, that the canyons had some such width as the valleys possess to-day; for in that case the branch valleys would have established accordant junctions with them, and the present hanging relation of the branch valleys would remain unexplained. This difficulty Professor Gregory proposes to remove by assuming that "if the major valleys be regarded as a reticular system formed along fractures which gaped open at the uplift of the country . . . the [greater] depths of the main valleys as compared with some of their tributaries is a natural consequence of the more rapid denudation along the tectonic ruptures". But no evidence whatever is given to prove that the main valleys of Preglacial time were formed in this highly hypothetical manner, nor is any reticular valley system of such origin known elsewhere, for the newly deepened valleys of other broadly uplifted regions lie, in the vast majority of cases, along essentially the same courses that they followed before uplift. Indeed, until a reticular system of valleys occupying gaping fractures is shown to exist in some recently elevated region, the gratuitous supposition that the main valleys around Snowdon are of that extraordinary origin has no value.

A profile from Snowdon across the valley of Lake Cwellyn to Mynydd Mawr is introduced to illustrate the contrast between the theories of strong and of slight glacial erosion. "The areas in solid black represent the amount of solid rock removed on the alternative hypothesis that the valley had been excavated approximately to its

present depth [and width] by pre-Glacial streams." Nothing is easier than to draw such a diagram; the difficulty comes in proving that the Preglacial valley truly had the width and depth there assigned to it. If it had any such width, its branch valley must have had an accordant junction with it, but as a matter of fact the branch hangs over the main valley. An additional difficulty would be found in justifying the assumption that the profile given for the Snowdon crest and for a cwm beneath it correctly represents the result of normal erosion in Preglacial time; yet such an assumption is made, for no " solid black " is added to indicate that the mountain profile has been perceptibly modified by glacial erosion.

It is then concluded that " according to this interpretation the topography of Snowdon at the beginning of the glaciation was essentially the same as it is now ", and therefore that glacial erosion has been of small measure. Like the reticular system of fracture valleys this conclusion can have little value until a never-glaciated mountain district of altitude similar to that of North Wales is found, in which the effect of a sub-recent uplift in reviving normal erosion has been to produce huge cwms under sharp-edged mountain crests, and half-mile-wide side valleys hanging over still wider main valleys, with vigorous streams plunging down narrow clefts between the two. Mountains and valleys of such forms do not exist outside of deglaciated regions, and a great body of excellent evidence indicates that their peculiar forms are the product of glacial erosion.

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Recent Sinking of Ocean Level.

Sir,—Professor Daly's speculation in the June number of this Magazine regarding the possibility of a recent worldwide sinking of sea-level calls for exposition of the facts as regards the British Isles. The writer feels somewhat at fault in the matter as he has made a statement of results without evidence and expected it to be accepted. Under the circumstances Professor Daly can hardly be blamed for setting one statement against another, and considering that perhaps the facts may be as required by his theory. It should be pointed out, however, that there is not really, as Professor Daly has implied, any conflict between the writer's account of the so-called 25 ft. beach and those of Sir A. Geikie [1] and Hull. As regards Kinahan's discussion of the raised beaches of Ireland, it can confidently be said that what is not absolute error in it is so indefinite as to have little meaning. To him anything served as evidence of a shoreline, from a glacial corrie or a drift-bank to a limestone escarpment. The lowest of his horizontal shorelines is by his own statement only 4 feet above mean tide level, so that it is not clear

[1] Anniversary Address to the Geological Society, 1904.

how it could be distinct from the modern shore. His statements, moreover, do not agree with those of Geikie and Hull.

Now to put the facts as briefly as possible. There are three sets of raised beaches traceable over considerable areas in the British Isles, (1) the pre-Glacial, (2) the Late Glacial, (3) the Neolithic (so-called 25 ft.). The submerged forests rest on the sediments of (2), and are overlain by those of (3). The Late Glacial and Neolithic beaches are thus quite distinct. The Neolithic beach is the best developed. It does not occur in the South of England and Ireland, where the only known raised shorelines are pre-Glacial. As regards the demonstration of the warping of the Neolithic beach, the writer has in his possession a notebook containing some hundreds of measurements made by H. B. Maufe and himself in various parts of the country, and covering in a rough way most of the coasts where the beach is found. The measurements were made either with reference to a comparable point on the modern shore or to high-water mark, or to both, where both were determinable. Many extended stretches of coast outside the area of the beach have also been examined without finding any trace of it. These observations have never been published because of their incompleteness. They are, however, amply sufficient to demonstrate the deformation of the beach and its approximation to or disappearance under sea-level along the periphery of its area of distribution. The exact position of the zero isobase is very difficult to determine, hence the writer's admission in a letter to Professor Daly that it might lie further south than shown in the diagram referred to. The average gradient is only one or two inches to the mile.

As regards dates, which Professor Daly expressly asks for, and climatic conditions, which must interest him, we have fortunately some very definite facts, which are in agreement with observations on the continent of Europe. The beach was formed in Early Neolithic or Campignian times, and elevated to nearly its present surface in late Neolithic times. Campignian implements are found embedded in it 12 feet below the surface, and polished stone axe-heads lie on its surface not many feet above present high water-mark. Its fauna indicates a climate some degrees warmer than that of the present day.

With Professor Daly's contention that eustatic movements of ocean level have taken place in recent geological times, the writer is in perfect agreement, but that the latest movement has been a negative one is not supported by the evidence in this country or on the continent. Outside the zero isobase of the Neolithic beach, in Ireland, England, and Denmark, Neolithic remains are found beneath sea-level, indicating a distinct positive movement. The widely distributed submerged forests dating from early Neolithic or immediately pre-Neolithic times onwards provide very good evidence of a general submergence. The very puzzling Micmac terrace, in its horizontality so unlike the post-Glacial beaches of